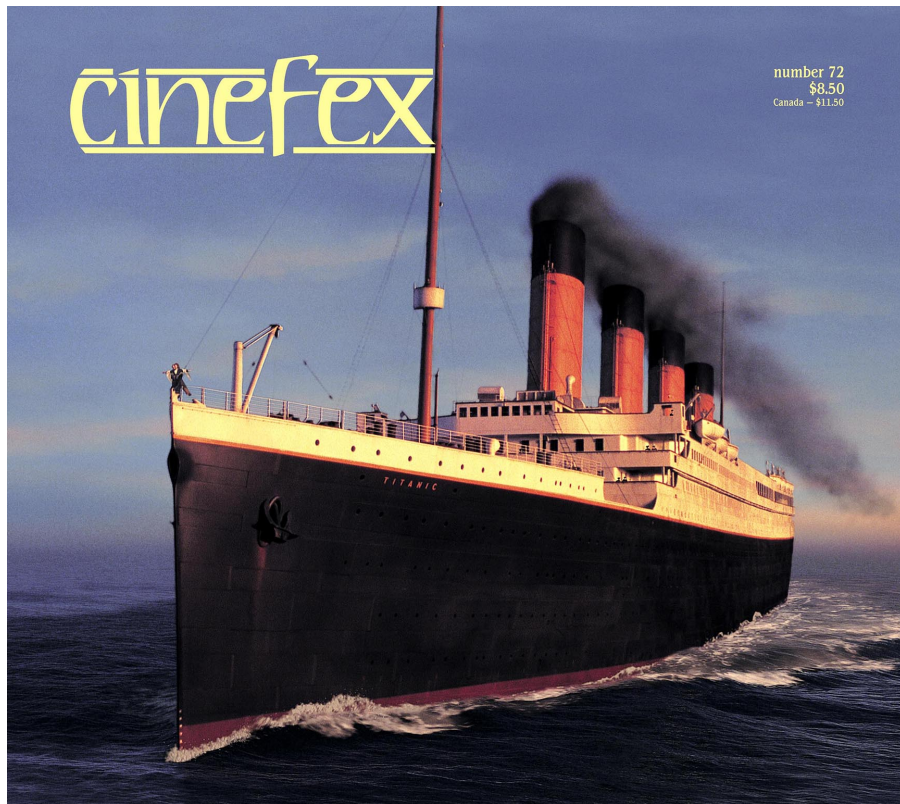


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Back to Titanic 15

Titanic is an apt title for the latest film from director James Cameron, denoting not only the subject matter of the picture, but the scope of the endeavor, as well. On his odyssey to bring the story of the 1912 maritime disaster to the screen, Cameron went to the bottom of the North Atlantic to photograph the actual *Titanic* wreck, then reconstructed the celebrated ship, almost full-size—and sank it—at a studio built expressly to house the massive production. *Article by Don Shay.*

Ship of Dreams 82

Convinced that total verisimilitude was essential for *Titanic*, Cameron challenged Digital Domain and visual effects supervisor Robert Legato to blur the line between full-size photography and miniature work by constructing an enormous model of the ship, then placing it in a digital ocean environment and populating it with computer-generated people to capture, in intimate detail, the expansive elegance of the liner at sea and the horror of its untimely demise. *Article by Don Shay.*

Titanic Aftermath 137

During principal photography and into postproduction, as the visual effects workload for *Titanic* increased from 150 shots to more than 500, a production-level effects department was established to assign and monitor the overflow workload, which was farmed out to seventeen separate facilities collectively contributing everything from complex compositing and miniature photography to matte paintings and computer animation. *Article by Jody Duncan.*

COVER—Lovers take flight on the bow of the *Titanic*.

BACK TO TITANIC

ARTICLE BY DON SHAY



She was the biggest, most luxurious ship of her day. Eleven stories tall and four city blocks long, she put to sea for her maiden voyage on April 10, 1912, carrying 1316 passengers and 891 crew members. Steaming through the North Atlantic on her fifth night out, she struck an iceberg shortly before midnight, rupturing her hull and flooding her forward compartments. With no recourse but to abandon ship, the captain ordered that lifeboats be loaded and lowered, aware that there were enough for only half of the people on board. Still, many of them were dispatched less than full. As the ship continued to take on weight, the bow sank and the stern rose out of the water. Splitting in half at the midsection, the 46,000-ton vessel elevated quickly to a full vertical position, bobbed like a cork for a few awful moments, and then plunged downward in a rush. Two hours and forty minutes after the collision, the ocean liner widely proclaimed as unsinkable was swallowed by the sea- as were 1502 of her passengers and crew.

Slightly more than eighty-three years later, a deep-sea submersible settled gently onto the boat deck of the Titanic, now a rusted hulk under two and a half miles of water, and through its circular viewing port James Cameron surveyed the remains of the once great ship that had occupied his mind and his heart for the better part of three years- and would continue to do so for another two.

Three movies prior, while researching deep submergence technology in preparation for *The Abyss*, Cameron had visited the Woods Hole Oceanographic Institution, in Massachusetts, and met with Robert Ballard, who in 1985 had made headlines by finding the long-lost wreck of the Titanic. "Until then," recalled Cameron, "I really had zero interest in the Titanic. I knew it was a big ship that sank. I knew a few of the rudimentary elements of the story- the band playing, women and children first, a lot of people dying- that's about it." Years later, in a lull between projects after *Terminator 2*, Cameron happened upon a videotape of *A Night to Remember*, the esteemed 1958 film on the sinking of the Titanic. "I must have bought it at some point and never watched it. But now, having met Ballard in the interim, I decided to check it out. As I sat there viewing it, I thought, you know, somebody should remake this. Then I started thinking that a pretty amazing film could be done by juxtaposing images of the wreck as it sits today

with images of what happened on that night long ago, sort of collapsing time in a way that only cinema can do- like the paleolithic bone thrown in the air in 2001 turning into the spaceship, editing out, literally in a single cut, three million years of human Evolution.”

The seed was planted. While Cameron believed that a new film on the Titanic would demand the highest attention to detail and historical accuracy, he did not feel that that extended to maintaining the documentary-style approach employed by *A Night to Remember*. “I thought it was not artistically interesting to just follow a bunch of historical characters, never getting to know any of them very well and therefore never really getting involved in the event at an emotional level. I figured the best way to get in touch with the emotion of the event would be to take one set of characters and tell the story as a love story — because only by telling it as a love story can you appreciate the loss of separation and the loss caused by death. To me, what happened to the Titanic is inherently romantic in the darkest sense of the word. Certainly it’s not the greatest tragedy of the twentieth century, but it’s one that has a great effect upon us because of its emotionality, its poignancy. So I came up with the idea of an ill-fated love story- a very young love story because I wanted a survivor who could still be alive today. If I had thought of this idea ten years ago, that would not have been a problem- but I didn’t. In fact, one of the reasons I decided to go with Titanic as my next film when I did was because I knew that if I made it the film after that, I’d be telling the story of a survivor who was 105. As it is, she’s 101- but that’s still within the realm of credibility. I didn’t want her to be some Guinness world record holder, because that would have strained the tether, that connection between our time and the event.”

Delving deeply into the historical record for a framework of real events and characters against which to play his fictional Romeo and Juliet love story, Cameron crafted an ultra-detailed treatment for Titanic and presented it to Twentieth Century Fox where his company, Lightstorm Entertainment, had a long-term production deal. In addition to the obvious- securing a production commitment- high on his personal agenda was convincing the studio to send him to the actual Titanic wreck site to film it for the modern-day segments that would anchor his period narrative. “Part of the appeal of this project- right from the inception- was that it might afford me an opportunity to actually dive on the Titanic,” admitted Cameron. “It was a romantic notion- as much personal as professional- but I felt that doing it would imbue the film with a sense of veracity it might not otherwise have. Obviously we could do the whole thing with state-of-the-art models and digital effects- and we would need some of those in any event- but how much would it cost? With some informal budgeting, I figured a couple of million dollars- which was just about exactly what it would cost to go to the ship and film it. Adding in the shots we knew we would have to do with models anyway, there was actually about a half-million-dollar shortfall- but I felt that the value to the film from a publicity standpoint might easily be worth that additional amount of money. And Fox agreed with that evaluation.”

With the budget for the deep dive approved- but without a greenlight to proceed with the film- Cameron made arrangements for the Akademik Keldysh to take him and a small Lightstorm crew to the Titanic. A marine research vessel flying the Russian flag, the Keldysh was the only ship of its type equipped with two deep-sea submersibles- Mir 1 and Mir 2- essential for

narrative filmmaking since one could be used as a camera platform to photograph the other in scenes with the Titanic.

Before the expedition could embark, however, two essential pieces of equipment had to be built. Both needed to withstand the extreme conditions present under two and half miles of water. One was a tethered ROV- a remotely operated vehicle outfitted with a video camera- that could be deployed from Mir 2 to prowl around the wreck. The other was a custom two-perf camera that could be mounted outside Mir 1 and operated from within. Since there was no way to reload at the bottom of the ocean, the two-perf format allowed a single film load to last twice as long as it would in standard four-perf, while still maintaining a widescreen aspect ratio. "The camera held a 500-foot load," noted Cameron, "which was the equivalent of a 1000-foot load. In addition, I knew we would be undercranking at 14 or 16 frames per second, because everything moves slowly underwater, especially submarines. So the run time was around fifteen minutes per dive." Both construction assignments fell to Lightstorm Technologies- a small R&D unit within the company headed by engineer Mike Cameron.

Of even greater concern than the camera was what surrounded it. "The housing for the camera was a titanium cylinder, about three feet long and ten inches in diameter," explained Cameron. "Mike was into underwater photography, understood it well, and he got together with some other experts in the field to create the four-inch-thick borosilicate glass dome ports that we would have to shoot through, because the pressure at the depth we were going to be was 6500 pounds per square inch. Multiply that by the number of square inches of glass in the front port for the camera, and you get 1.1 million pounds of pressure on a piece of glass nine and a half inches in diameter. Under those circumstances, the consequences of the glass failing were extreme- because if it did, water would race down inside of the tube, probably exceeding hypersonic velocity before it reached the back of the housing, and demolish the camera down to a molecular level. Worse, the stainless steel end cap would then blow off with the kinetic energy of a cannon shell and go right through the sphere of the submarine. So our lives depended on that glass not shattering. My brother's advice to me was, 'Don't ever have the back end of the housing pointing toward the sub.' And my response was: 'Mike, the back of the housing is always going to be pointing toward the sub, because the camera's going to be pointing away from the sub. That's the whole idea!'"

While these preparations were underway, John Bruno- a friend and associate who had served as visual effects supervisor on *The Abyss* and *True Lies*- developed storyboards for scenes Cameron intended to capture during the shoot. Although he would not see *Titanic* through to the end- a go-ahead on *Virus*, his first feature as a director, was imminent- Bruno spent five months consulting on the project and would be one of the few members of the Lightstorm contingent, aside from Cameron himself, to actually dive on the *Titanic*. Also in preparation for the deep dive, modelmakers at



Digital Domain- the effects studio founded by Cameron in partnership with Scott Ross and Stan Winston- constructed a twelve-foot-long replica of the wreck which would be taken along on the

Keldysh so that Cameron could use it as a visual aid in demonstrating desired sub choreography for the Russian crew members- most of whom spoke little English.

When all was in readiness, the film expedition departed from Halifax, Nova Scotia, on a course for the Titanic wreck site where Cameron would spend much of September 1995 hunched over camera controls and a video monitor inside a seven-foot-diameter canister at the bottom of the ocean. "I suppose most people would think that seeing the Titanic for the first time would trigger an incredible wave of emotion," noted Cameron, "but it was not that way for me. By the time I actually got to the ship and was looking at it, the number of steps it had taken to get there, to be ready and able to photograph, made the experience so intensely technical that, for me, it was like Neil Armstrong stepping out onto the moon. Neil wasn't thinking about the beauty, the starkness, the isolation. He was thinking: 'Okay, I'm ten minutes behind the mission profile. I've got to do this, I've got to do that.' You get so wrapped up in the technical details of whatever you're doing that it distances you from the event. You're not emotionally in the moment- you're just doing your job.

"Our first pass over the Titanic was messed up and confused and chaotic- not in the slightest what I had anticipated it would be- because of currents and poor visibility and the fact that I had put a lot of faith in the sub pilots, who had dived the ship before. Unfortunately, they had dived ten thousand other things in the meantime, and had sort of forgotten the layout of the ship. As it turned out, I knew the layout better than they did, though my knowledge was entirely theoretical. Half the time they didn't know where they were. It was very frustrating. Then there was the visibility. From

photography I had studied before the trip, I expected visibility between 75 and 125 feet. But it turned out that the bottom conditions had changed since the last expeditions, and we never got better than 35 or 40 feet- which was very disappointing, because we had gone down there with the technology needed to get very wide shots of the wreck, and it turned out we weren't going to get those. In addition, the ROV was not working and our lights failed to deploy properly. So the first dive was a total bust. It was two hours down and two and a half up, with about ten to twelve hours actually at the wreck site, and we returned without any usable footage at all. It was just a mess, and I came back convinced that the whole trip was going to be a write-off."

The situation looked less grim after a night's sleep. Prior to the next dive, equipment malfunctions were resolved and the camera was fitted with a wider-angle lens. "I had to retool my thinking because of the visibility," said Cameron. "We had brought different lenses to do different things, so I switched over to the widest possible lens- which is what you always do

James Cameron's part of the Keldysh set of Cameron's deep-sea camera and the movie the Titanic wreck.



To meet the demands of the production, a full studio comprised of an eight-acre tank and three large stages was built in only a hundred days near the Mexican seaside town of Rosarito.

when visibility is poor, you get closer to your subject and shoot through less water.” The second dive—two days after the first—was markedly better. “We had recrewed the subs so I could communicate with someone who spoke English in the other one— which helped a lot in coordinating our movements over the ship. Things were starting to click and I was starting to get some results. At one point there was a lull in the action while we were waiting for the other sub to maneuver around into position. We’re sitting right on the boat deck, drinking some tea, and suddenly it hits me— I’m on the Titanic. Right here is where it all happened. It honestly hadn’t struck me until then. We completed the dive and went back to the ship. I debriefed and did all the technical stuff I had to do, then went to my room to rest. A wave of sadness swept over me— sadness for the ship and sadness for the people who were on it. Before that day, the Titanic had been abstract for me. It had been a story. It had been a movie. But to actually be there and see the ship and to know from my research the people involved— the ones who survived and the ones who did not— and to have the curse of a vivid imagination, it was a pretty overwhelming feeling. I don’t mind admitting that I cried.”

Cameron had had an epiphany that would alter both his perception of the mission and the gauge by which he would judge its success. “After that, I wasn’t quite so gung-ho about charging around and getting shots. In a sense, I felt a little more respectful of the wreck. It sounds goofy, but that’s how I felt. Before that, my sole motivation to get great images was aesthetic. It was a filmmaker’s motivation. But now it was more like: ‘I just want to capture this. I want to get this on film somehow.’ And that sort of stayed with me through the whole movie, when we were on the set and reproducing events. My goal was always to capture the spirit of the Titanic.”

For his last dive on the Titanic, Cameron decided to do something that no one had ever done before. “I wanted to use our ROV to go inside the ship and look around— which was not part of the original plan. Robert Ballard, when he was down there with Jason Jr.— which was a multimillion-dollar robot— dropped it into a big open hole that had been the stairwell. He went down a couple of decks and had a look around, but he didn’t go any further than that because he didn’t want to risk his expensive research tool. We, on the other hand, just had our cheesy Hollywood prop version— which, when you think about it, was quite impressive since there are maybe ten ROVs in the whole world that can go to that depth. It gave us troubles at first— it turned out that the oil used to pressure-compensate the thrusters had the wrong viscosity for the pressure and temperature down there— but once we got it going, it functioned flawlessly. So I decided to send it inside the ship to look around.”

The first mission was aborted when a stray bit of wood lodged in the prop and the ROV had to be hauled out using the retractable robot arm on the sub. Back on the Keldysh, wire mesh installed over the thrusters afforded a quick fix. “Then we went back and did it again. In order to protect the wreck and not damage anything, or foul ourselves, what we did was move the ROV about four or five feet, set it down, let the silt clear, scan with the camera, then do it again. A little move, lots of scanning and analysis, another little move, more scanning and analysis— just like the Sojourner on Mars. In this manner, we managed to go deep inside the ship and video all around in different rooms— and we got some pretty amazing stuff. Ballard concluded, some time back, that wood-boring mollusks had eaten all the wood in the ship. But we found, in

certain areas anyway, that that was not true. A lot of ghostly remains of the ship's former grandeur are still there. No one had seen it since 1912."

After twelve dives on the Titanic- each with more than ten hours on site- Cameron realized with no little irony that he had spent more time on the Titanic than any of her passengers had. It was time to set course for Los Angeles and prepare for the even greater challenge ahead.

Ten months would pass before cameras rolled again on the story of Rose Dewitt Bukater and Jack Dawson- two young people on opposite ends of the social spectrum- who meet and fall in love aboard the Titanic on her short maiden voyage into history. During that time, Cameron would fashion his treatment- a highly detailed, if informal, proposal he termed a 'scriptment'- into a three-hour screenplay for an epic union of drama and spectacle rarely attempted since the cinematic heyday of David Lean.

A top-notch production team was needed to bring Titanic to the screen. Joining Cameron as producer was Jon Landau, a former executive vice president of feature production at Twentieth Century Fox, who had forged a professional relationship with the filmmaker during True Lies. Acting as executive producer was Rae Sanchini, president of Lightstorm Entertainment and a former senior vice president at Carolco Pictures during the Terminator 2 days. Returning for his third Cameron outing- after Aliens and True Lies- was veteran production designer Peter Lamont, a regular on the James Bond series. Another early team member was special effects coordinator

Thomas L. Fisher, a master at large-scale physical effects, who had worked on Terminator 2 and True Lies. Visual effects of spectacular complexity would be served up by Digital Domain under the supervision of Robert Legato, selected for the assignment shortly after completing Apollo 13, for which he received an Academy Award nomination. Serving as technical advisors for the production were writer-historian Don Lynch and illustrator Ken Marschall, two eminent authorities on the Titanic.



Serving as the visual centerpiece of the film was an almost full-size replica of the Titanic, fabricated in the studio tank.

For his two leads, Jim Cameron resisted studio urgings to choose from a list of proven boxoffice stars– Brad Pitt was proposed for the Jack Dawson role– because he believed strongly that the story needed young actors who could play late teens. Selected at last was a pair of Academy Award nominees, Leonardo DiCaprio and Kate Winslet, whom Cameron felt imbued the spirit of his characters and could aptly convey the passion and tragedy of first love lost. Backing them up were Billy Zane as Rose’s millionaire fiancé Cal Hockley, Frances Fisher as her status-conscious mother Ruth, and Kathy Bates as Molly Brown, one of the Titanic’s most celebrated real-life passengers.

Just how– and where– Titanic might be filmed was a subject of lingering concern. Countless options were proposed, considered and ultimately rejected. “We were faced with a unique dilemma,” said Jon Landau. “We had to show a pristine ship sailing the ocean, and then we had to show it sinking. If we had had to deal with only one of those elements, it would have been a hundred

times easier– but we were faced with both. When we first started exploring possibilities, Jim felt seriously that we would have to go out on open water. So the first thing we looked at was building our set on a tanker– one of those enormous ships with a flat deck where they stack rows and rows of cargo containers.” As a visual aid, Peter Lamont and his art department produced a small model representing such a vessel, and fashioned on top of it a mock- up of the proposed Titanic set. The plan was to re-create the upper levels of the passenger liner atop the expansive cargo vessel, which from stem to stern was roughly the same length as the Titanic. Rather than construct the set down the center of the ship, however, it would be offset to one side– slightly overhanging the deck so that an extension representing the Titanic’s hull could be wrapped over the edge and carried down to the waterline. Not only would this afford a near-complete profile of the Titanic, but with modern cargo vessels being about twice as wide as the vintage ocean liner, it would also leave about half of the host ship’s deck open for lighting equipment, camera cranes and other moviemaking paraphernalia.

With a seagoing platform, there were numerous options as to where the set could be built and eventually photographed. “We wanted the light to be pretty,” observed Landau, “so we started thinking about the northern hemisphere during the summer, when you have white nights. We looked at Sweden and Poland, in particular. For a while, Poland looked promising enough that we went over to the Gdansk shipyards and talked to them about helping us build our ship, since



Construction crews race to complete the gigantic set as filming commences in adjoining stages.

labor costs were very low there. We knew we could pull a lot of our props and set dressing out of the rest of Europe- and there were all these great European faces for extras.”

The next issue to address was the sinking of the ship. Cameron was determined that the Titanic’s final hours not be depicted solely in the miniature realm. He wanted the full-size ship- or at least part of it- to be able to submerge with actors and stunt performers on board. The set built atop the cargo vessel for sailing scenes would therefore need to be dismantled and reassembled at some alternate location where it could be lowered underwater. “We considered going to Malta- which was then the largest tank facility in the world- but it was too small to accommodate the ship we planned to build,” stated Landau. “There was not much stage support there, either- we would have had to go somewhere else and split up the show. The Bond stage at Pinewood presented similar problems. We thought of everything from building the set in a quarry or a pit mine that we could fill with water, to building it on barges that we could sink and refloat. For a long while, we wanted to do it indoors where we could have optimal control. We looked at blimp hangars, submarine plants in South Carolina, any huge structure we could locate. Nothing was quite right.”

What triggered a final solution were some of the early tests Digital Domain was doing with computer generated water. “When we started seeing how good those first tests looked, “ stated Landau, “I began questioning whether it was really necessary to film on open water. If we built our ship on land, instead, near the ocean where there was a water horizon line behind it, we could photograph on board without actually having to move because the only real sense of motion from a ship comes when you look down. Any shots that did require us to see water motion could be done with CG. I proposed this to Jim- who immediately took the ball and ran with it. There was no doubt that a land-based situation- especially one with some sort of tank where we could sink the ship- would give him tremendous flexibility in shooting, without all of the problems associated with being on open water. And logistically, there would be far better access for equipment and such.”

After much consideration, it was determined that the most satisfying and economical solution - economical in the long term, at least- would be to build a tank facility and studio from scratch. “We could have modified the tank at Malta to suit our needs,” observed Landau, “but what we would have been doing- what Fox would have been doing- would be investing serious capital in someone else’s infrastructure and then walking away from it at the end of the show. So we went to the studio and proposed that we find an oceanfront site in Mexico- somewhere close to the border- where we could build a tank and a studio inexpensively, at least by U.S. standards. With everything at one location, we could move back and forth from the ship to the stages, from outdoors to indoors as weather or construction or scheduling dictated, with a minimal amount of disruption. Certainly the cost would be higher than using an existing facility, but by designing the studio so that it could accommodate nearly any feature- especially ones that have water aspects to them- Fox would have a permanent long-term asset. The studio was hesitantly open to the idea, so we began scouting for a spot where we could do it.”

Although several locations were considered, the most ideal was a hundred-acre tract of undeveloped oceanfront property near Rosarito, just thirty miles south of San Diego on the Baja California peninsula. Production team members descended on the site, sketching out tank configurations and determining optimal placement of the stages and support structures. Orientation of the ship was a critical issue. "By this time," explained production supervisor Gig Rackauskas, "we knew that the ship set was going to be in one position only. Picking it up and swinging it around would not be an option. It had to be placed just right." A twenty-five-foot study model of the Titanic- constructed by Digital Domain and used

by Cameron to determine camera choreography during the previsualization phase- was trucked into Mexico and placed on a platform at the Rosarito site. "Jim came down with most of the department heads and spent a whole day with a lipstick camera, lining up shots on the ship and determining what would be visible behind it. Mainly we wanted to avoid seeing lights from the town at night. We hired some local peones to hang around all day; and whenever we needed them, they would run over and help us haul the boat around from spot to spot- wherever Jim wanted to see it." So that Cameron could have an idea of what would be visible from the deck levels of the Titanic- some sixty feet off the ground- a construction crane was on hand to afford the director a bird's-eye view of the surroundings. Also factored into the equation were weather patterns for the region. By facing the ship northward into the prevailing winds, smoke blown from the funnels would stream backwards, creating the impression that the ship was underway. Based on the findings of the day, an optimal placement of the ship set was determined- and from that, the overall dimensions and orientation of the tank that would surround it.



Makeup artist Greg Cannom ages actress Gloria Stuart for her present-day role as Titanic survivor Rose Calvert, whose recollections of the ship's ill-fated voyage form the narrative of the film.



On a camera platform suspended from a tower crane, director of photography Russell Carpenter studies his lighting setup.



Since the night of the sinking was moonless, giant bounce cards and lighted balloons were deployed to cast an even illumination over the set.

Although cranes of varying sizes and configurations were engaged in the construction effort, the most imposing was an enormous tower crane that was to become a permanent fixture at the studio. A tower crane had proven most useful on *True Lies*, before and during location filming atop a Miami skyscraper, and Cameron thought a similar one would be a valuable and versatile asset for *Titanic*. Mounted on rails running the full length of the tank, it would provide formidable muscle power throughout the construction phase. And of perhaps even greater appeal, it could later be used during the shoot as a lighting or camera platform. “We located a crane– not a new one by any means– and had it stripped down and serviced and certified before sending it to Mexico,” recalled marine coordinator Lance Julian. “With 162 feet under the hook and 192 feet of jib, it was tall enough to clear the ship and long enough to extend thirty feet beyond the port side. So there wasn’t much it couldn’t cover. And with its own generator and fuel tanks, it was totally independent– which was important, especially after the tank was filled. It could go through the water at about ten feet per second – which meant it could travel the entire length of the ship in four minutes. And at the very end of the jib, it could still lift four thousand pounds.”

Elsewhere on the site, three enclosed stages were being erected. The largest– Stage 2– was a sprawling thirty-foot-deep tank stage spacious enough to accommodate a replica of the *Titanic*’s first-class dining room, which would be built on a platform and lowered into the water during filming of the sinking scenes. The remaining two– Stages 3 and 4– were smaller by half and more conventionally configured, although one of those, too, would eventually be fitted with a sizable tank. “Early on,” remarked Ferguson, “we looked at renting canvas structures for our stages. It seemed obvious that would be the fastest and cheapest way to go. When we got into it, though, we found that we could build steel structures– actual permanent buildings– for less than it would cost to rent canvas ones over the time period we were going to be needing them. And we found a company in the States that could manufacture a building for us in only three weeks.” Additional permanent structures were erected to serve as production offices and dressing rooms; but beyond that, the studio looked rather like a refugee camp, with workshops and support functions housed in clusters of tents and trailers.

Construction of the *Titanic* set was overseen by supervising art director Charles Lee, an architect and engineer by training, who had served under Peter Lamont on two previous projects, including *True Lies*. “Peter’s experience is incredibly vast,” marveled Lee. “He’s been in this business for more than fifty years, and just about everything he knows about film ends up in every project we do– every possibility for saving money or improving a shot or getting a bit more distance or understanding color and its effect. On the projects we’ve done together, Peter usually handles the conceptual end of things while I deal more with the engineering– which is pretty much how it went on *Titanic*.”

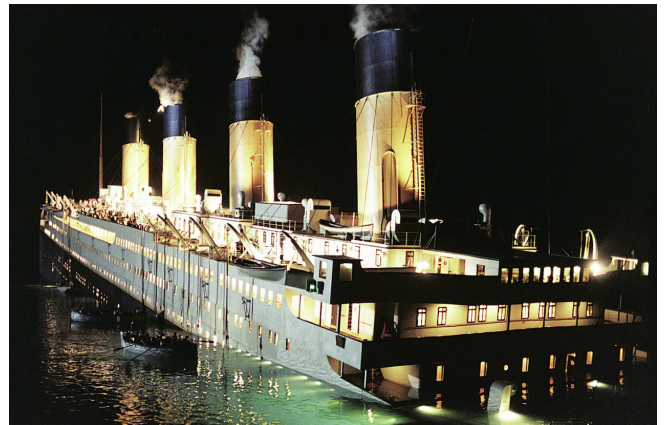


Only the starboard side of the ship was fully detailed.

Previous movie reenactments of the Titanic story had depicted the enormity of the ship principally through suggestion, with miniatures and a modest selection of interior and exterior set pieces. Cameron wanted to present the ship- inarguably the largest and grandest of her day- in a manner more in keeping with her true proportions and overall visual impact. "At various times," said Lee, "we considered building the entire ship- at least everything that was visible. If we had built it on giant ocean-going barges that we could sink- as we thought we might for a while- we could have lashed several of those together and done that. Another idea was to go to Gdansk and have them actually build the Titanic. Then we were going to take it out into the Atlantic and sink it. They could have done it for about \$25 million- and it might have been worth it- but it would have taken two and a half years to build it."

By the time the Rosarito site was selected and set construction commenced, the scope of the shipbuilding effort had been scaled back to slightly more practicable proportions. The upper portion of the ship would be constructed in its entirety- the four funnels, the bridge and the boat deck, the promenade deck just below, the forward and aft well decks and the poop deck. All would be featured prominently in the main unit shoot. Also of importance was the bow. However, since the forecastle directly behind it was not, the decision was made to omit that. So the ship set began at the forward well deck- with a bow piece standing apart, about a hundred feet out, enabling action to be filmed on it, from low angles, with the ship visible behind. Shots requiring inclusion of the forecastle would be augmented with visual effects.

Exactly how much ship should be built was the subject of considerable deliberation. "When I first started on the script," recalled Cameron, "I was determined to write the best Titanic story I could and show as much of the ship as I could- because the ship is the world of the film. It had to be fascinating and it had to be everything the Titanic was. I wanted the Turkish baths, I wanted the swimming pool, I wanted all of the things that made it inconceivable that a ship like this could sink. To do that, it was important not to feature just two or three places on the Titanic, but to show as much of it as possible. And when it struck that iceberg, I wanted to convey cinematically, viscerally, what it would be like for a ship the size of a small city to actually break apart and sink. So I incorporated all of this into my screenplay- without much thought as to how it could be done, because that's crippling from a writer's standpoint."



The ship set was laboriously lowered and reconfigured at a fixed six-degree angle for scenes after the Titanic strikes an iceberg and begins to sink.

After his storyline was fleshed out in detail, Cameron assembled his key production staff and initiated discussion on what it would take to bring the script to the screen. What could be done with models? With computer graphics? What could be built full-size? "We began by building a twenty-five-foot study model of the Titanic," stated Cameron, "and we shot a whole lot of video on it at Digital Domain- mapping out the action of the film and seeing what areas of the ship we

would actually need to have. The model was too big to move very much, so when it came time to simulate sinking it, we built a framework of mylar sheeting that went around it at the waterline. Then we would move the sheeting up and angle it- removing the forecastle and the well deck as they submerged- and photograph all the stages of the sinking just by tilting the camera. It was quite effective. It really looked like the Titanic was going down into the water. By the time we finished those early previsualizations, we had just about every major shot in the movie blocked out.”

From there, it was a matter of determining what should be done live and what could be done with models or other effects techniques. “It turned out that the Titanic was a very difficult photographic subject because you could see so much of it from different parts of the ship,” said Cameron. “So even though we started out trying to limit ourselves on what we were going to build and what we were going to detail, the more we got into it, the more we realized that we had a three-hour movie that, with the exception of the first twenty minutes, takes place entirely on the Titanic. We had scene after scene after scene on this ship- and unless we built a lot of it, we were going to start running out of places to shoot. At one point, we asked ourselves if we could get by without the funnels- which were huge- or maybe build one and just the base of the others. But then it was, ‘If we do that, how can I shoot this and how can I shoot that?’

Everything we tried to cut back really limited our angles. So we ended up building more and more and more. In the end, we wound up with everything but the forecastle- probably seven-eighths of the ship- and frankly, we should have built the forecastle, too, because it turned out to be more of a pain in the ass not to have built it than to have built it. Could we have gotten by with less? Maybe. But I think it wouldn’t have made sense to build three-quarters of what we built- because the limitations on shooting would have tripled. We would really need to have built much less and do a lot more with models- which are certainly not inexpensive, either, if you’re trying to get them up to a level of photorealism equivalent with the physical production. I believe there was not an easier way to achieve the specific imagery we wanted for this film.”

In a bid to conserve resources and reduce construction time, Peter Lamont proposed that the ship be shortened overall by ten percent- a modification he successfully argued would be imperceptible on film. “The idea was not to reduce the elevation of the ship by ten percent,” commented Lee, “but rather take out slices along the length in places that would not be obvious. So we did that. We took out eighteen-foot slices between each of the stacks and a twenty-foot slice from the poop deck. In that way, we were able to reduce the length of the ship to ninety percent and still keep everything on it scaled at one hundred percent- almost everything. There were a few exceptions. When we shortened the ship, we found that the masts and the stacks looked tall by comparison, so we shortened those by ten percent. The only other things we reduced in size were the lifeboats and the davits- because if we had made them full-size and positioned them along our shortened boat deck, the last lifeboat would have fallen in the wrong place.”

Even with the forward eighth of the ship unbuilt and the remainder compressed by ten percent, the Titanic set was still the length of two football fields. To lessen the enormous physical demands of first tilting the ship and then sinking it in the tank, the set was fabricated in two huge sections that joined between the second and third funnel. Each had its own steel

framework inside, designed- in close coordination with the art department- by Tommy Fisher. "Since the whole set was going to be some forty feet off the ground," stated Fisher, "we wanted to have the framework for it also serve as the main structural support, to conserve on the weight. So each part of the ship had a series of interconnected trusses over which the deck pieces would fit like a shell. Some of the doors along the promenade deck led to interiors that were used in the film; but more often than not, if you opened a door, all you would see would be wooden walkways and crisscrossed girders. It was like a bridge inside. Once I came up with the concept, we hired a structural engineering firm to design the trusses. Then we went to another company that fabricated all the steel pieces and shipped them to us. It was like a giant Erector set. Everything was designed to be bolted together because we knew it would be easier to find people who could put bolts in than it would be to find people who could weld. I had my regular crew of about fifteen that I brought down from the States; and with another fifteen or so Mexicans that we hired locally, we put the whole thing together ourselves. Then the construction department came in and put all the walls on it to make it look like a ship."

It was apparent to all that construction of the ship set could not be delayed until after the tank and the framework were finished. Nor could other major sets await the completion of necessary stage space. Yet there were no facilities and no workers who could begin immediately at the Rosarito site. "We knew that in order to make our timeline for the production schedule we needed to be building sets in advance of the stages and the facilities being ready," observed Jon Landau. "We looked at bringing in construction crews and housing them and finding temporary workspace for them- as opposed to having the work done in Mexico City and shipped up to Rosarito- and it turned out to be much more cost effective to go the Mexico City route. Mexico City is a major film center with a large labor force - excellent set builders and craftsmen- so it was an easy decision."

Most of the interior sets- including the first-class dining room and the massive grand staircase leading down to it- were fabricated in Mexico City, shipped in pieces to Rosarito, and assembled on site by a work force that grew to some five hundred strong as production drew near. Significant portions of the ship exterior- the deck houses and many of the props and fittings- were also manufactured in Mexico City. Although the deck areas reproduced would eventually need to be situated forty-five feet above the tank, it was clearly advantageous to do as much of the construction and assembly as possible with the massive steel frames sitting on the ground. Once this was accomplished, Almas International, a company specializing in the movement of buildings and other large structures, was called in. Using hydraulic jacks, Almas raised the two ship sections in five-foot increments, building as they went a supporting framework of steel pillars and tubular bents underneath.

After the ship sections- each well in excess of a million pounds- were in place, finishing work could begin. The most obvious addition was a false hull- on the starboard side only- that extended from the promenade deck to the water. The port side- closest to the ocean- revealed only naked scaffolding and steel work below the finished deck levels. Shots requiring full port-side views of the ship would be filmed using the starboard side, with the footage flopped in postproduction. To insure that there was no telltale evidence of this deception, all signage on

the ship was prepared in alternate mirror-image versions and utilized in scenes that would be optically reversed.

The starboard hull was high-grade plywood, with an overlay of panels and bolts for texture and detail. Four hundred windows and portholes, delineating the various deck levels, were made of plexiglass. “When we got the ship finished and painted,” commented Lee, “we were appalled to find that it looked like a model. Well, I tell you, after building something seven hundred feet long, we were pretty damned determined it was not going to look like a model.” One of the problems seemed to be the unbroken uniformity of the hull and the portholes. “We decided to go in and put images behind every single one of the portholes.

We had a lot of photographs showing various cabin interiors throughout the ship. Some were actually from the Titanic, while others were from her sister ship, the Olympic, which sailed for twenty-five years and was much more extensively photographed. We scanned the photos into a computer and colorized them, and then made enlargements to fit the different-sized portholes. Laminated against the salt water, and with a slight curvature, they helped create a real sense of depth. Also, as much as possible, we put the proper image behind each porthole- at least to the extent of placing the different-class cabins. We knew Cameron was going to be all over that ship; and there was no telling what might end up on film.”



Panic sets in as the last of the lifeboats are lowered, leaving more than 1500 people still on board the doomed vessel.

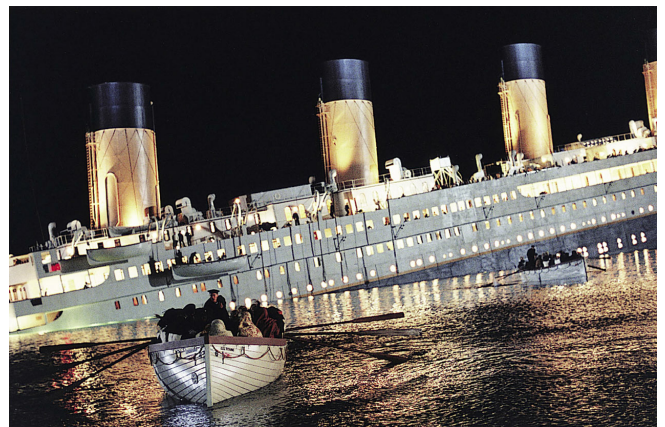
While sets and stages progressed along parallel courses toward the mid-September start of main unit photography at the Rosarito site- christened Fox Studios Baja- Cameron gathered cast and crew and headed for Nova Scotia. There, in keeping with the level of realism set for the production, the Akademik Keldysh had again been chartered, not for further dives on the Titanic, but as a setting for the present-day scenes that would bookend the 1912 love story. Cast in the role of treasure hunter Brock Lovett was Bill Paxton, a Cameron favorite and veteran of *The Terminator*, *Aliens* and *True Lies*. For the pivotal part of Titanic survivor Rose Calvert- formerly Rose Dewitt Bukater and now a 101-year-old widowed grandmother- Cameron recruited 86-year-old Gloria Stuart. A familiar film presence in the thirties- appearing in *The Old Dark House* and *The Invisible Man*, among others- Stuart had retired from acting by the mid-forties and taken up painting. *Titanic* was her first film role since.

"I never for a minute considered putting Kate Winslet in old-age makeup," stated Cameron. "Not even the greatest of the great, Dick Smith, could take someone Kate's age and make her look 101- at least not believably. Try to take a round, girlish, young face, with full cheeks and full lips, and turn it into an aged face where most of the fat is gone, the skin is deeply wrinkled and the eye sockets are deep- no one would buy it. Aging is a subtractive process, for the most part, and makeup is an additive process."

Having firmly rejected any thought of putting Kate Winslet in old-age makeup for the part of Old Rose, Cameron nonetheless recognized that even Gloria Stuart- who could have passed for twenty years younger than she was- needed help to look the age she was supposed to be in the film. Enlisted to add years to her well-preserved visage was Academy Award-winning makeup artist Greg Cannom. "Jon Landau called me up and said they were doing this Titanic movie in Canada, that it was starting the next week, and they wanted me to work on it," recalled Cannom. "I had just come off two huge films, and I was exhausted and didn't want to travel anywhere. But Jon sent the script over, and I read it that



Using the tower crane as a camera platform afforded much flexibility in shooting.



For views of the ship's port side- which was unfinished- the starboard side was optically flopped.

night- and I was so blown away with the realization that this was going to make cinematic history, that I knew right then that I had to be part of it.” Gloria Stuart presented herself at the Cannom Creations studio the next day, and Cannom did a test makeup on her, which he photographed and sent via Federal Express to the production. “That was Friday. On Monday afternoon, I got a call from Bill Paxton who said he was going to need some tattoos, and could I help. I said: ‘Well, I don’t know. Am I on the show?’ And he said: ‘Yeah. I was talking with Jim and he couldn’t believe how terrific the makeup looked.’ So I’m going: ‘Oh. It would be nice if someone told me.’ On Tuesday, I finally heard from Jon Landau- Jim Cameron called, too- and they said: ‘The makeup looked incredible. We want you to do this. We’re shooting in Nova Scotia. Can you leave tomorrow?’”

The location shoot was divided, more or less evenly, between time spent on the Keldysh and time spent in a Halifax warehouse where the ship’s laboratory and imaging shack were built. “When we were on the boat,” Cannom continued, “it took us about two hours to get to the location, and I would do the makeup as we went out- which was tricky because the ship was pitching up and down and I was a bit queasy at first. I began by using tattoo colors to paint fine lines all over her face- around her eyes, down the nasal folds, around her mouth, everything- then I hand-painted a huge number of age spots on the sides of her face and neck. After that, I used three coats of old-age stipple on her face- everywhere except her nose- and four coats on her neck. I wrinkled the hell out of her. The nice thing about stipple over tattoo colors was that it created a very nice sense of transparency. Her eyes were the most critical area because Jim told me he was going to be doing extremely tight closeups on them. As my final step, I lightly raked a bit of prosthetic makeup color over her entire face so that it highlighted every little wrinkle. I was scared to death on this film- with all the closeups and not being able to see dailies or anything- but Jim was really great. He was always telling me how good the makeup looked.”

After three weeks of shooting on the ship and in the warehouse- plus a couple of days in Malibu for scenes of Rose in her California home- the film shut down in early August and Cameron returned to preproduction activities. Included among these was a one-day shoot aboard the S.S. Lane Victory, a restored World War II merchant ship that was chartered from its berth in San Pedro and taken to sea off the California coast so that authentic bow and stern wakes, similar in nature to the Titanic’s, could be filmed for later incorporation into visual effects shots planned by Digital Domain.

When the main unit reconvened in Rosarito on September 16, filming commenced inside Stages 3 and 4 where a number of interior sets stood ready for use. Absent from the proceedings was director of photography Caleb Deschanel, who had left the production after completing the Nova Scotia portion of the shoot. In his place was Russell Carpenter, who had won his Cameron stripes previously with *True Lies* and the T2/3D theme park attraction. Extricating himself from prior commitments, Carpenter arrived in Rosarito with only two weeks in which to prepare. “I had just enough time to come down and be awed by the spectacle of a city being built, almost overnight, in order to accommodate the filming of this enormous picture,” stated Carpenter. “What struck me the most, I think, was: ‘My God, how will they ever be ready to shoot? There’s nothing here.’ The ship was basically a framework that represented maybe a third of what it

would eventually become. I could sort of see where things would go when it was finished- but now it was a steel structure in a very large hole in the ground, covered with swarms of humanity all working at fever pitch, hammering and welding. The big tank stage where the dining room was being built wasn't even enclosed yet. From what I saw, I determined that I would have to take this project in blocks, focus on the smaller sets we would start to film at the beginning, then send my gaffer, John Buckley, and his crew out on lighting expeditions during the weeks and months ahead as the bigger sets were finished."

Carpenter spent much of his scant preparation time making aesthetic choices and determining an appropriate photographic style for the picture. "I began by taking a crash course in period photography. I resourced several period films whose photography I especially admire- *Heaven's Gate*, *The Natural*, *Howard's End*- and I incorporated some things from those into my own visual game plan. In terms of color palette, *Titanic* is probably the warmest Jim Cameron film yet produced. I particularly went for golds and ambers- which seemed appropriate to the gilded surroundings and the golden age of the great luxury ships- so we tended to skew our interiors and exteriors over to that end of the spectrum, at least early on. Later in the film, though, we wind up squarely in Jim Cameron territory in terms of the blue night look- which was driven, in part, by Jim's wish to be true to the spirit of Ken Marschall's paintings of the *Titanic* disaster, which are very much in the cyan-blue spectrum. So I would say that the beginning of the movie was influenced by the paintings of John Singer Sargent- who was a much sought-after portrait painter at the turn of the century- and the end of the movie by the paintings of Ken Marschall."



As water rises inside the ship, Jack Dawson (Leonardo DiCaprio) and Rose Dewitt Bukater (Kate Winslet) slog through the first-class dining room- a huge set built on a hydraulic rig that lowered it into a thirty-foot-deep stage tank.



Steerage passengers, kept below deck while first-class passengers filled the lifeboats, struggle to get topside.

Photography commenced on Stage 3 in a set representing the lavish suite shared by Rose and Cal- in reality to have been occupied by White Star Line owner J. Pierpont Morgan who, fortuitously in retrospect, canceled his booking the day before the Titanic set sail. After exhausting all finished interiors within the first couple of weeks, Cameron and company moved on to a large, but shallow, above-ground tank constructed on Stage 4 for scenes of lifeboats and passengers in the water during and after the ship's sinking. Originally, these scenes had been considered for the big outdoor tank, but it quickly became apparent that prolonged exposure to the water, especially at night, would create a situation in which no acting at all would be required to depict the effects of hypothermia. So a heated freshwater tank was erected on stage and backed, depending upon shot requirements, by either a greenscreen or a painted horizon.

As the air temperature on the night the Titanic sank was in the thirties, and the water temperature was somewhat less, Cameron was well aware that anyone on or near the water ought to be exhaling clouds of vapor. The temperature at which breath vaporizes varies depending upon the amount of humidity in the air- a factor controllable to some degree on stage. "Tommy Fisher thought we could get breath to vaporize somewhere between fifty and fifty-five degrees," noted Cameron. "I knew from experience that the water would have to be colder than that, or it would steam. I also knew that if we were going to put actors in fifty-degree water, they would only be able to perform for ten or fifteen minutes at a time- maybe thirty. We talked about having warming tanks immediately adjacent, and of putting Leonardo into a hot-water suit- which would be a standard diving solution to the problem- and Kate in a wetsuit underneath her costume. But that offered no protection for hands and feet, and hypothermia would take place over time. Actors are always going to say: 'Let me be cold. I can use it for the scene.' And that works for about four takes. After that, it's: 'Get me out of this fucking water. I can act being cold.' So our actors would have been in the water for ten minutes and out for thirty, and it would have taken two weeks to shoot what we needed, instead of two or three days." Gauging what that would cost against the anticipated expense of adding breath as a postproduction visual effect, Cameron opted for the latter and shot the scenes in a warm environment.

After finishing in the shallow tank, the company moved on to Stage 2 where the first-class dining saloon and the grand staircase had been assembled on a platform at the bottom of the thirty-foot-deep tank. Authentically accoutered with Titanic-style furnishings and reproductions of White Star china and crystal, the enormous set was filmed upon- dry and level- for a week. Then the platform supporting it was connected to eight hydraulic actuators powerful enough to raise and lower the set into water, which was pumped into the tank.



Jack and Rose try to escape a flooded labyrinth of lower-deck corridors.

“It was huge-scale engineering,” said Cameron, “and to my knowledge, no one had ever tried sinking anything nearly the size of this set some two or three stories into water. We considered all kinds of approaches– like building a lock mechanism of the sort used to lift ships through a canal– but most of them were flawed for one reason or another. Then one day, I was sitting with Tommy Fisher in the conference room at Lightstorm, and an idea came to me. I grabbed a pad and drew a quick sketch, and said to him, ‘Why can’t we have cables connected to hydraulic rams– six or eight really big ones– and run them over pulleys so that they go down and attach to the set and just run it up and down like an elevator?’ Tommy looked at my drawing, and his expression was skeptical– but there was a gleam in his eye that told me: ‘It could be done. It would be really expensive and no one would be crazy enough to do it– but it would probably work.’ So we started looking into it. The key element was figuring out how we could amortize the expense of the hydraulic system by using it on the dining room and the other sets that had to flood on stage, then moving it to the outdoor tank and using it to sink the forward part of the ship. Once we did that, the whole idea began to seem feasible from both a technical and economic standpoint.”

Essential elements of the system, designed by Fisher and built in California by Mayo Hydraulics, were installed on Stage 2 prior to the assembly of the dining room set. “It didn’t look it,” said Fisher, “but the dining room and grand staircase weighed almost as much as the ship– 1.3 million pounds as opposed to 1.4 million. It was a three-story set– very impressive.” Tilted slightly and lowered into the tank so that the seawater appeared to be inching higher and higher, the dining room was the setting for a desperate chase through the foundering ship– a scene Cameron ultimately cut from the film to shorten the running time.

“Even though I ended up using very little of the scene,” commented Cameron, “it was valuable in the sense that it was a test bed for how we were going to do all of the sinking stuff. There was quite a learning curve– especially for myself and Josh McLaglen, the first AD. Just getting everyone on and off the set was difficult in that environment– and safety was always an issue. We were in a two-hundred-foot-long set– with a ceiling over our heads– hung by cables over a thirty-foot pool of water. And this whole vast machine was controlled by a laptop computer. If for some reason the set were to fall, it would go right to the bottom of the tank– and us with it. So everyone was briefed on emergency procedures– and there were plenty of lifeguards ready to race in and save people.

“After our first half-day on the set, though, we were all getting pretty cocky. It was like being in a room– except we could make it go up and down and water would come pouring in. Jimmy Muro was running around with a Steadicam and I had a hand-held camera, and we were getting shots of water pouring in over the carpet– things like that. It was cool. Then suddenly, for no apparent reason, the set plunged five feet. It let out a terrible creaking groan, pieces started falling off the ceiling, and water began rushing in. And man,



I'll tell you- it got real! 'Everybody out of the set, right now!' Josh and I were on either side of the room like fascist ushers. 'Out of the set!' And it was beautiful. People dropped their tools and equipment, whatever they were doing, and headed straight for the exits. They did exactly what they were supposed to do- except for one camera assistant who ran back to get the Steadicam. Which was admirable in a way- except that it was not. I yelled at her to get out. She began to, and then turned back again. Now there's just two of us on the set, because I'm not leaving until everyone else is out. Finally I got her out- and we had a little discussion about doing what you're supposed to do, not what you think you should do, because somebody else could get hurt trying to save you. We never found out, for sure, what caused the problem- some sort of computer glitch- but after that, everyone understood that this was for real. The set could really sink- and we could really be on the Titanic. From there on, nobody dozed through the safety briefings."

Of potentially greater peril was a later scene in which water scaling the boat deck of the now fast-sinking Titanic explodes through the crystal dome above the grand staircase and pours down onto frantic stragglers trying to slosh their way topside. "We mounted three large cargo containers above the set," commented Fisher, "and filled them with water- probably fifty thousand gallons or more. Each container had a trap door and a chute leading to the dome. We opened all three at once- and this water crashed through the dome and onto a bunch of stunt people we had down below. Several were knocked off the staircase and swept away. It was quite a scene. We were prepared to do it a second time if we had to- but there were cameras covering it from all over and everything went perfectly on the first take."

The first major sequence to be shot outdoors depicted the Titanic's final moments afloat. Torn apart from the rest of the ship, the elevated stern section takes on water in a monumental rush, upends to a full vertical position, pauses for a few terrifying moments, and then plunges into the sea carrying more than a thousand stranded passengers and crew members with it. Although wide views of the event would be achieved via miniatures with digital augmentation, dramatic shots of men and women slipping and falling away as the ship rises and then descends, and of

For scenes later in the sinking scenario, the entire front half of the ship was detached and installed on a hydraulic riser that allowed it to be lowered- on camera- into thirty-four feet of water.



Water pours over the front rail of the promenade deck as the set lowers into the tank.



Passengers and crew attempt to launch one of the collapsible lifeboats as water rushes up the boat deck.

Jack and Rose clinging desperately to the outer rail of the poop deck as the sea rushes up to meet them, were achieved largely in the live-action realm.

To render this doable, a means had to be devised to elevate the entire poop deck portion of the ship set- a structure weighing roughly a hundred tons- to a full upright position. "We built a big platform ninety feet long by ninety feet wide- which was the size of the set piece- that we mounted on a pivot axis," explained Tommy Fisher. "Then, with the set bolted on top, we used simple hydraulics to tilt it up to ninety degrees. We had planned on contracting out the hydraulics- as we did with the other big system- but the poop deck got moved up on the shooting schedule and there wasn't time to do that. So we built it ourselves. It was a powerful system. We could tilt the set up to ninety degrees in only fifteen seconds. A lot of it was done at around thirty degrees, though- with the camera tipped to make it look steeper- because at ninety degrees, when a stuntman fell, he was in and out of frames in a flash. It was total free-fall. Working at a lesser angle slowed things down a bit, and there was a lot more control."

To anyone actually on the set, the angle of tilt was both disorienting and deceptive. "You read accounts of the Titanic and you see paintings of it at a forty-five-degree angle where everybody is sort of running around on deck," remarked Cameron. "Well, I'm here to tell you, anything above twenty-five degrees and you ain't running- you're holding on for your life. Get to forty-five degrees, and it's like hanging over a straight drop. Our perception of level is so ingrained, Evolutionarily, that even a slight deviation seems like a lot."

With airbags below and greenscreen backings strategically in place, up to 150 stunt performers- as many as ten at a time on descender rigs for high falls- took their places on the set and enacted their character's final moments as the poop deck tilted skyward like a particularly sadistic theme park ride while they slipped and scrambled and lost their grip, striking deck fittings and each other as they tumbled into The Abyss. Not all of the shots featured Jack and Rose close enough to be identified; but for those that did, Leonardo DiCaprio and Kate Winslet gamely took their places on the aft railing- the highest point when the set was erect- where they were cabled securely to prevent them from becoming involuntary stunt players.

"The stunt crew was out there for weeks ahead of time rehearsing on the tilting set," commented Cameron. "I walked the set repeatedly with Simon Crane, the stunt coordinator, and we replaced so many elements on it that we called it the 'Nerf set' because everything was either made out of foam or covered with foam. All of the steel surfaces that somebody might fall on had six inches of foam over them, painted to look like part of the structure. And there were big rubber capstans- some of which we had to replace digitally because they squished when anyone fell on them. So even though the set looked horrific, it was almost impossible to hit something and get hurt. Or so I thought."

Everything went fine for the first couple of days. "We got up to forty-five degrees and we had twenty or thirty stunt people all tumbling or doing falls at the same time. Then we took it up to full vertical and things started going wrong. In the space of literally two stunt takes, we had two serious injuries. A stuntgirl got her cheekbone fractured and a guy broke his ankle. Then somebody else cracked a rib. Suddenly I was faced with something I had never experienced as a director, except one time when a guy got his arm burned on *True Lies*. People were getting hurt on my set. The danger was not with any given stunt.

Any given stunt was very safe and containable, and had been done in the movies ten thousand times before. But the cumulative effect of so many people all doing stunts at the same time increased the possibility of random elements- people getting out of position, not being where they were supposed to be. If you have a hundred stunt players all doing stunts simultaneously, that's the equivalent of shooting one stunt per day for one hundred days. Do that same thing five times a day, over a two-day period, and that's like a thousand stunt days. So even though we planned everything down to the nth degree, we got burned on the small statistical inevitability that if you do semi-dangerous stuff, even the right way, for a long enough period of time, somebody will get injured. And that's exactly what happened. But I have a zero tolerance philosophy when it comes to set injuries and I didn't want to play that microscopic average anymore. So from there on out, there were no falls on the poop deck. Everyone was harnessed and just dangling. Anytime I needed a fall, it was going to be a CG figure doing it."

From a photographic standpoint, the principal challenge of the poop deck sequence- and, indeed, all of the night scenes- was illumination.

"Technically the ship was dark," observed Russ Carpenter. "There was no moon- only stars- and by this time all the lights on the ship had gone out. Early on, in discussions with Jim about how to light a moonless night, we decided that the film would be lit by the imagination of the viewer's mind. Given that, we took a lot of liberties in terms of what one would actually see on a moonless night. So the trick was adding a lot of light without making it look like we had. Complicating this particular sequence was the fact that Jim had many moving cameras shooting at once. As a result, our lighting was forced back so far that it became rather like stadium lighting, without any of the finer nuances I would have added if I'd been able to do so. Another complication was that the sequence was shot once outside and



Desperate swimmers, swept off the sinking ship, threaten to swamp one of the collapsibles.



Shots requiring the miniature ship to be seen in the background were filmed in a shallow stage tank backed with greenscreen material.

twice inside- under very different conditions. After we did the full poop deck outside, a smaller section at the very back was put on a tilting rig on stage so that closeups of Kate and Leo and the people immediately around them could be shot with both green and black backings. Trying to keep a consistency of lighting throughout was difficult."

Having survived the tilting shots, the poop deck took its place at the rear of the Titanic set, which by mid-November was fully assembled and detailed and ready to shoot. The first scenes to be filmed on the set were of the giant ship preparing to depart Southampton on her maiden voyage. A replica of the dock was constructed over the tank, backed by a building facade boldly lettered with 'White Star Line'- in reverse since the finished starboard side of the ship set was doubling for the port side in the scene. A thousand extras- in multi-class period wardrobe courtesy of costume designer Deborah Scott- were needed to reenact the boarding and provisioning of the world's largest and most luxurious ocean liner.

When the departure scene was completed, the Southampton dock set was promptly struck and the Titanic was now at sea. Several weeks of day and nighttime shooting followed before Cameron launched into his re-creation of the ship's final hours on her fifth night out of port. No stranger to large-scale lighting assignments, Russ Carpenter nevertheless found the Titanic a most challenging subject- especially at night. Even the practical lighting was monumental. "An enormous amount of light emanated from the Titanic," related Carpenter. "It was like a floating city of light. And that was something we very much wanted to capture- that sense of its being a jewel out in the darkness. Given that we were re-creating an object from history, there was certain lighting in place that we had to be true to. But then, to actually illuminate specific areas of the deck and enhance that impression of the Titanic as a floating city of light, we went through and sprinkled an additional, say, thirty percent practicals throughout the ship- just so it would read better on film. John Buckley began by counting portholes and windows on the ship. We determined that we would need a 2K behind each one, so that was about seven hundred to start with- just on the starboard side. Then we built up from there, with all the lights on the upper deck, which had to be lit on both sides. Eventually, in all, we had three thousand plus lights on that ship- with 140 miles of cable to service them. It was amazing that everything functioned as well as it did, because sometimes you would walk down into certain sections of the ship, and it would look like Pac Bell in the fifties, where everything was just a mass of wires and cables."

Though statistically and logistically awesome, practical lighting was nonetheless only part of the assignment. For most shots of and on the ship, it was also necessary to devise a means of providing overall low-key illumination adequate for photographic purposes, yet consistent in visual impression with the moonless night of historical record. "One of the earliest things we discussed was using the tower crane as a lighting platform," remarked Carpenter. "The idea was to hang one of the biggest bounce cards ever created- sixty by twenty-five feet- out at the end of the boom, over the ship. Then we would mount three 10Ks up near the top of the tower and direct them at the card so the light would bounce down and evenly illuminate a rather large section of the ship."

The bounce card concept quickly went the way of the dinosaur, however, when Jim Cameron realized that he had at his fingertips the biggest camera crane in history. A cage was promptly

assembled and suspended from the trolley hook with either a Wescam or a Spacecam unit mounted underneath. Large enough to accommodate Cameron, Carpenter and a two-man camera crew, it provided a perfect vantage point for the director to orchestrate his signature sweeping camera moves. Over a radio headset Cameron was able to direct the crane operator to advance along the track, pivot the boom arm, extend the trolley and raise or lower the cage, thus allowing him total freedom to hover or make compound helicopter-style moves over any part of the ship without the rotor turbulence and safety concerns- not to mention noise- associated with utilizing an actual helicopter.

With the tower crane coopted by Cameron, an alternative was needed for lighting the set. "We tried different things," commented Carpenter. "One of the most interesting was balloons. Lighting with balloons is something new- I believe it began in Europe. A few companies have figured out a way to install high-output, low-weight light sources inside helium-filled balloons. The helium lifts the balloon on a cable through which power is fed to the light. The advantage to this approach is that the illumination is quite beautiful, and you can move these large, soft sources quite quickly. We got a number of these balloons- which were sixteen feet in diameter- and we used at least two at a time whenever we could. The problem was that high winds often came up with very little warning. We had nights where fifty-mile-an-hour winds would appear out of nowhere, blowing the balloons across our man-made lake. Some of them were damaged."

Since high winds rendered both balloons and bounce cards ineffective, a backup was required. "Jim came up with the idea of using a cylinder rather than a bounce card," said Carpenter, "reasoning that since a cylinder was totally rounded, the wind would never find an edge to catch. So we liberated a cylinder from the ship- a wooden one, eighteen feet in diameter- and tried hanging it from a crane and bouncing lights off it. It proved to be a very good idea, even though it was a smaller target to hit with our lights. We got several others and used those also. The cylinders were infinitely more stable than what we'd been using."

Although use of the tower crane as a camera platform was emancipating for the director, it complicated matters for the forty-man on-set lighting crew that was trying to keep up with him. "When Jim was up on the crane- which was often- he could literally survey the entire ship in just a few seconds," explained Carpenter. "Very often there were shots where he wanted to see a lot of territory- or run a character halfway down the ship at night. Jim likes big camera moves. The challenge for us, logistically, was providing ample illumination over very large portions of the ship- while at the same time finding places to hide our lights."

By the time production broke for the Christmas holidays, all of the scenes of the ship in level orientation were in the can. When cast and crew returned after New Year's, they would find the Titanic tipped forward at a disorienting six-degree angle, her bow fully submerged and her stern some forty feet aloft. Getting it that way was a major undertaking- one that first required the tank to be drained. "Because of the size of the job and the schedule we were on," said Gig Rackauskas, "we hired two companies to tilt the ship. Almas International, the firm that had lifted it into place for us and built the framework, would do the aft section while MIM- M Industrial Mechanical- would do the forward section. The original plan was to shoot with the ship tilted at three degrees for a while and then move on to six degrees. We were told it would take ten days to do each move- but it turned out to be a bigger job than anyone expected

because before we could tilt the ship we had to take it apart, take off the forward well deck, take off the aft well deck and poop deck, and remove a huge chunk of hull in order to separate the two halves. It turned out to be more like a three-week process. So we had to give up on the three-degree angle and go directly to six."

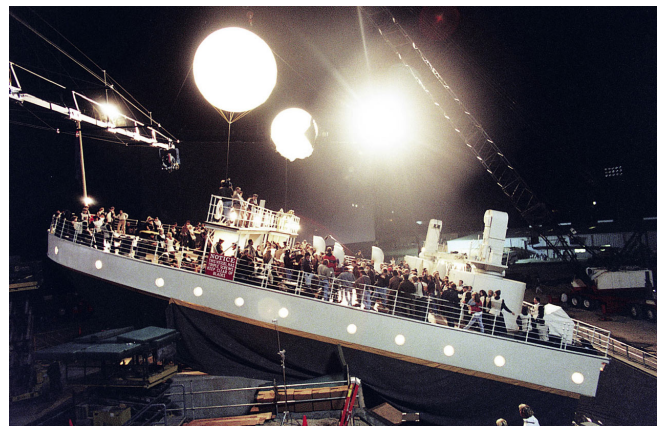
Almas and MIM employed totally different techniques to achieve the same end. "The people at MIM were ironworkers- really organized," commented Rackauskas. "They brought in these huge jacking beams and went to work- just picked up that ship and moved it. Before we knew it, they were done. It was amazing! Almas did it the old-fashioned way. They jacked the ship up at the top and then started slicing the steel framework away at an angle, lowering the ship about four feet a day until they got it to where it needed to be- which was about twenty-four feet down in the front. At one point there was some nail-biting- the last column line started to bend and the ship slipped forward a bit- but everything was quickly braced and stabilized. In the end, the two sections came together within a quarter of an inch. Everyone came back after New Year's and said: 'Wow! It's still in one piece.'"

The art department still had to stitch the two main sections of the ship back together and attend to a multitude of finishing details. Since everything forward of the bridge would be submerged when shooting recommenced, the tiny bow piece was completely removed, as was the forward well deck- which was now painted in two dimensions on the bottom of the tank so that its form could still be discerned underwater. "We had to reangle the mast to match the tilt of the ship," commented Charles Lee. "It was so large that we had anchored it right in the bottom of the tank- in a foundation twenty feet square and twelve feet deep. That was necessary because it had a cantilever. Jim wanted to be able to detach wires and get them out of the way any time he wanted- which you couldn't do with a guy mast. So we had to design an independently supported mast, from which we hung light-gauge wires that only appeared to be functional."

Because the great ship foundered slowly as her forward compartments took on water- nearly three hours passed from the time she struck the iceberg to the time she sank- Cameron was able to use the fixed-angle set for a considerable amount of filming, cheating the camera on



As the ship continues to take on water, the bow is pulled under while the stern rises skyward. Jack and Rose head for high ground.



For scenes showing hundreds of people crowding aft as the ship noses downward, the set's poop deck was mounted on a hydraulic platform that allowed it to tilt on end.

occasion to suggest a greater or lesser degree of tilt. After three weeks of shooting on the ship, the company moved back to Stage 2 where the waterlogged remains of the first-class dining room and grand staircase had been cleared and replaced with a maze of corridors and stairwells representing the steerage section. Dry and wet scenes of third-class passengers trying to escape from the bowels of the ship– and of Jack and Rose nearly being trapped by rising water and locked gates– were filmed over the next couple of weeks, after which the hydraulics controlling the stage platform were removed and transported to the outdoor tank where the Titanic set was being readied for its final scenes.

As perceived by Jim Cameron, the essential difference between his Titanic and previous cinematic reenactments of the tragedy was that, as the end neared, those earlier films had shifted focus from the ship to the lifeboats, showing the actual sinking from the point of view of the survivors. “Most of the eyewitness accounts are from people who got off in the lifeboats,” remarked Cameron, “and the last of those left the ship fifteen minutes before the final plunge. Only the two collapsibles were still on board near the end– and those got washed off the deck as they were being launched. About forty-five people who were swept overboard made it to those and survived. So more than ninety percent of the eyewitness accounts are from people who were in lifeboats four hundred yards away when the ship broke up and sank– and it was dark. Since the historical events in past Titanic movies were based on survivor accounts, they all seem to follow the same pattern. There’s a great amount of detail up until the point that the last lifeboat is launched; then the ship goes up in the air and sinks– usually in the space of one ten-second shot– and that’s it.”

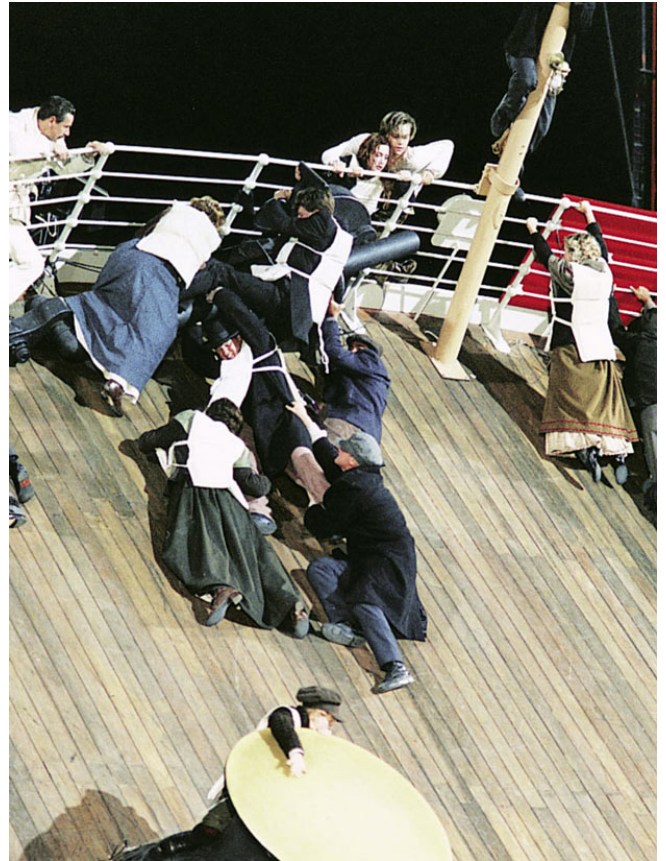
Considering this somehow dismissive of the hundreds left behind to die, Cameron wanted his audience to be right there with them– to go down with the Titanic, not view it from a distance. “To me, the most interesting part of the story is what happened on the ship after the last lifeboat left. What happened to those 1500 people? What about those 1500 untold stories? To me, that was a much more compelling area to explore– but also a sketchier one. There was no black box on the Titanic– no flight data recorder. Of the people who stayed with the ship through its final gyrations, only three or four survived. So to determine, as accurately as possible, what happened on the ship in those final minutes, I had to closely scrutinize the accounts of those very few, then cross-reference them with a straightforward, scientific, forensic analysis of the wreck, and finally try to put it all into one unified field theory that accounts for everything. I don’t know if I got it one hundred percent right– but I’ve talked with a lot of experts and I think it’s pretty close.” In order to tell the story of those last terrible minutes on the Titanic, Cameron knew that his cast and his cameras had to be on the ship as it made the plunge– hence the scenes of chaos and despair on the tilting poop deck. But even more was thought necessary. Prior to those scenes, he wanted the full forward half of his giant set to sink into the sea as those still on board were washed from the deck or scrabbled aft in a futile attempt to save themselves.

Before the epic-scale sinking could be effected, the forward section of the set had to be taken off the steel superstructure supporting it at the fixed six-degree angle and reconfigured. “We had to drain the tank,” explained Rackauskas, “and bring MIM back in to split the ship apart and lower the front. They brought in their own hydraulic system, set it up, lifted the ship, cut

out all the steel underneath and lowered it right down to the bottom of the deep tank.” The steel framework upon which the upper decks had been built would now serve as a riser driven by the massive hydraulics Tommy Fisher had designed to perform double duty on Stage 2. Eight steel cables attached to trunnions along the sides of the riser ran, through a series of pulleys, to an enclosed structure at the edge of the tank where the mechanisms were housed.

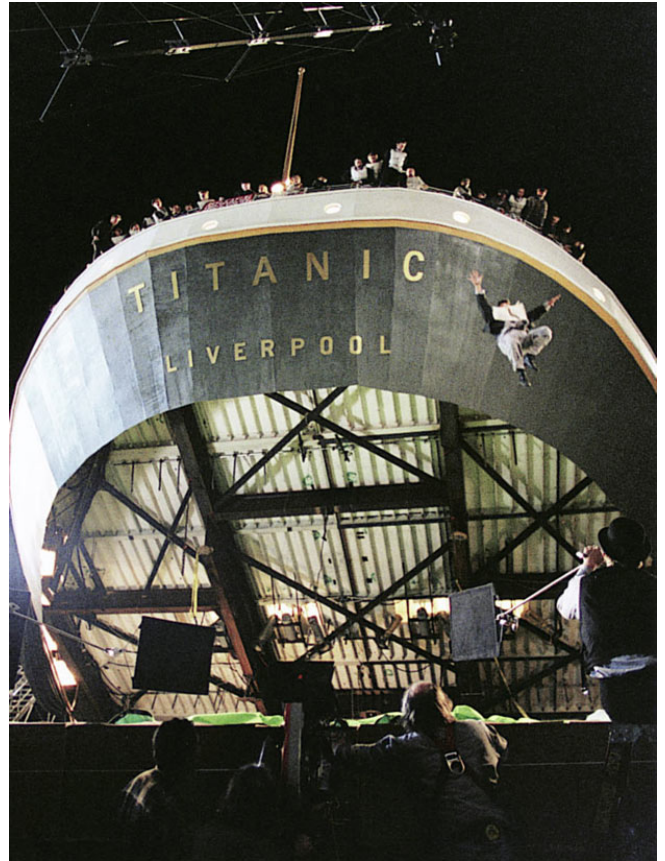
“The ship was like a big elevator,” commented Fisher. “By letting down the front cables and lifting on the rear ones, we could tilt it from six degrees down to about ten or twelve degrees— even roll it a bit. More importantly, we could lower the whole set thirty-four feet into the water— right to the base of the second funnel. We had eight hydraulic cylinders— seventeen feet long and a foot in diameter— which, because the cables were wrapped two-to-one, gave us the thirty-four feet of movement we needed. Everything ran off a computer. The computer was connected to a small model of the ship— a waldo kind of thing— which, in turn, was connected to the full-size hydraulics. When the computer told the waldo to move an inch, that translated to three feet on the big ship. The operator could sit at the computer, look out a small window at the ship, and control everything with two little joysticks.”

“We had a real problem with weight,” recalled Rackauskas. “The hydraulic system was designed to support 1 million pounds— but we were well over that. Apparently the construction crews built a lot more out of steel than they originally intended. In any event, the final weight of just the forward part of the ship was about 1.4 million pounds. Tommy Fisher was aghast. ‘Oh my God! How are we going to lift it?’ Eventually he solved the problem by building steel cages under the ship and filling them with big blocks of styrofoam. Another problem arose because of the scene in which Captain Smith is standing in the wheelhouse as the ship goes down and water explodes through the expanse of glass and engulfs him. For that to work, the wheelhouse had to be watertight, so we had a foam company come in and spray all around. What that did was add more buoyancy to the ship, making it too hard to pull under. It also kept the water inside every time the ship was dunked, making it harder still to lift it up again because of all the added weight. Tommy solved those problems by removing some of the styrofoam blocks and by installing valves that would keep the ship watertight, yet allow it to drain when needed. This was, after all, a prototype— one that had never been tested prior to use— so some problems were bound to arise.”



When the ship breaks in two, the stern section rises to a full vertical position and then plunges into the sea. Jack and Rose cling to the outer railing as the poop deck ascends.

Other modifications were made as filming progressed. “On the first day of shooting,” explained Cameron, “the ship wasn’t sinking fast enough. We were sinking at the maximum rate, according to the computer, but the set was going down very slowly- which meant that there was too much resistance. So I had the construction people go in and cut out all the decking on the inside of the ship and replace it with steel mesh. You could still walk on it safely, but the set was now like a giant parts dip tray- just a sieve on the inside. After that, it sank pretty fast. Later in the sequence, I had the effects guys try a maneuver where they lowered the set just enough for water to pour over the forward rails, creating a reservoir in the forward area. Then I had them lift it up a couple of feet out of the water, so that the set now weighed an extra half-million pounds. When it was released with all that extra weight, the set just plunged- which is what happened for real with the ship. For quite a while, the Titanic seemed to be sinking at a predictable rate. People in the lifeboats could see water creeping over portholes and up the side of the ship. What was not apparent was that the rate was going up logarithmically. Then there was a point, just as the water poured over the forward rails of the boat deck, when everything went crazy. The ship plunged so fast that water shot over and raced up the deck, knocking down hundreds of people and washing them off the ship. That was the beginning of the end- and I wanted to capture it on film.”

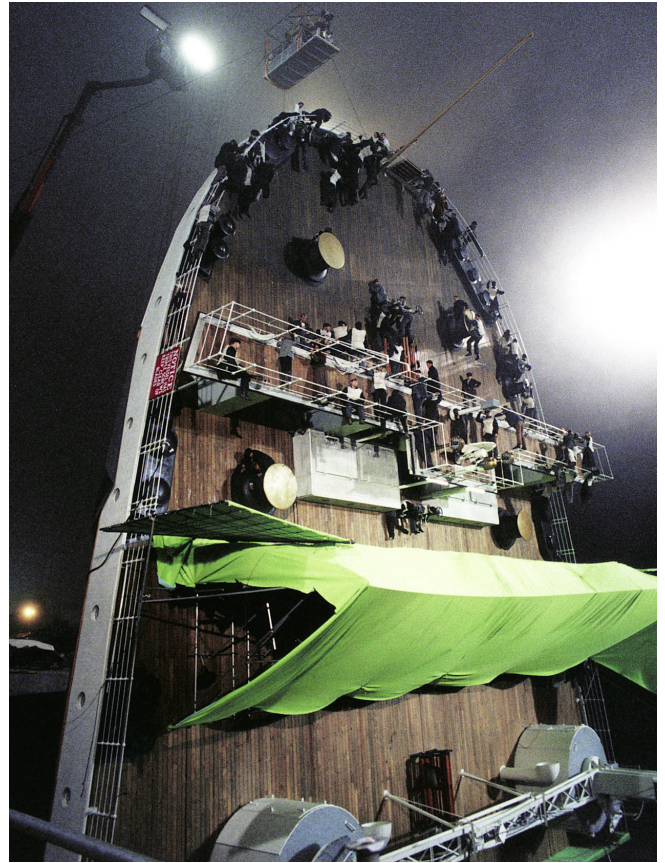


A stuntman leaps from the set into a green airbag.

Sinking the huge Titanic set was the last major challenge of the main unit shoot. "We had already sunk the dining room and the reception area and the labyrinth of third-class corridors and rooms," stated Cameron, "so we were old hands at running sets up and down. But this was an order of magnitude greater from a safety and logistical standpoint, because there were many shots where we had more than two hundred people on camera- on a moving set that could drop forty feet. If anyone had gotten trapped inside, it would have been all over. So the job was to figure out what the hydrodynamics were- how the water was going to move as it poured in and over the sides of the deck. If anyone was in the wrong place at the wrong time, they could easily be pushed through a door and taken down with the set. We had thirty lifeguards- wearing period wardrobe over wetsuits- interspersed among the crowd, some carrying bundles with floatation devices inside. Many of the steerage passengers would not release their luggage- everything they owned in the world was inside- so it was okay for people to be carrying bags. We had a buddy system and an emergency abort system- and a system of verbal and audio commands. No one was supposed to be more than fifteen feet from a lifeguard- even the stunt players- and if someone did get sucked into the set, we had people on the inside with breathing gear. It was all elaborately planned- and our precautions paid off. We had no incidents of any kind during that shoot- and it was a whole lot of fun."

The fun ended a few days later when production wrapped and Cameron returned to Los Angeles to edit the film and oversee postproduction.

Since well before the start of principal photography, Titanic had been a magnet for media interest- most of it focused on what the endeavor would wind up costing. Here was a film of such magnitude that Twentieth Century Fox delayed greenlighting the project for six months while budget issues were debated, and then, the week before shooting was to commence, decided to hedge its bet by entering into a co-financing deal with Paramount Pictures- an increasingly common gambit in recent years. With a budget believed to be well in excess of \$100 million- a figure never officially confirmed by the principal parties- Titanic was an easy target in a year when low-cost independent films were all the rage, winning critical and boxoffice favor and dominating the Academy Awards. What could Cameron- and the studios- be thinking? Only lunatics would make a \$100 million period piece with no bankable stars and no merchandising tie-ins- not even the chance of a sequel. As shooting progressed and the



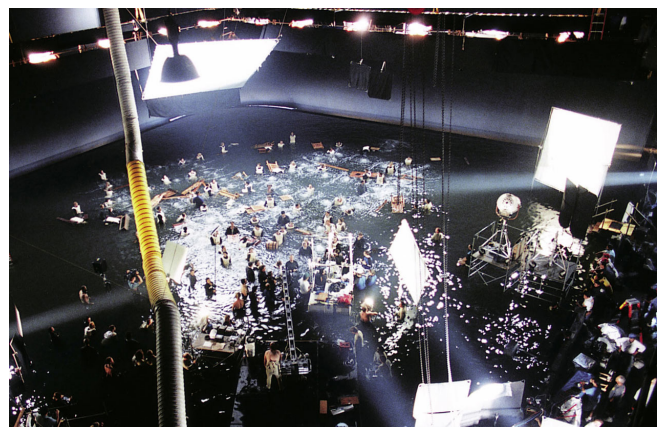
Stunt players cling to the upended set- padded and backed with greenscreen material so that the rest of the ship can be added digitally- as the crane-hung camera platform hovers above.

production went well over schedule, a firestorm of negative publicity descended upon both the film and the unyielding perfectionist at its helm. Cost speculations began to soar. \$120 million... \$170 million- the Waterworld benchmark...\$200 million...\$285 million. Through it all, the studios declined comment while Cameron maintained unwavering focus and continued filming.

When the main unit wrapped on March 22, the production was nearly six weeks behind schedule, and media attention now expanded to include speculation as to whether the plum July 2 release date carved out for the film could be met. Additional postproduction team members were enlisted, and seventeen companies were brought on in waves to handle the overflow of visual effects that were added as the film underwent final assembly. Still the likelihood of meeting the original release date diminished. Later dates in July and August were considered before a final announcement was made, just after Memorial Day, that Titanic would forego the summer altogether and opt instead for a berth in the prestigious year-end release schedule, on December 19. Perhaps with only a trace of cynicism, it was theorized that that was the date Cameron wanted all along.

Throughout it all, Jim Cameron defended his vision- and also the cost of bringing it to fruition. "I think the studio understood the necessity for this film to be visually compelling," said Cameron. "Otherwise they would never have agreed to spend \$120 million on it- which was the original budget. You don't make a \$120 million film and have it all take place in a drawing room environment. It has to be visually spectacular- and not just in the last five minutes when the ship sinks. How do you do that? I think you do it the way we did it. We wound up spending a lot more than we intended to spend- but we never did anything that was not in the plan. I believe the film very accurately represents that original \$120 million plan. The difficulty came in what it cost to create the plan versus what we thought it would cost. What happens when you get into a situation like that is that the studio responds by wanting to change the plan. But I don't change the plan- because frankly, once you start shooting, the only thing you can trust is the plan. You lose touch with the ability to see the overall thing. In a way, it's like being on the Titanic. People on the Titanic didn't know the ship was sinking until they were in the lifeboats and away from it and then saw the portholes going down into the water. It's no different when you're making a movie. You can see the part of the deck you're standing on, but you can't see all the way from the bow to the stern. So you have to trust the plan.

"So when the studio comes in, and says, 'We're going to take this out and this out and this out, and get you back on schedule,' my response to that is, 'No we're not- we need it.' And it then becomes a dialogue- a dialogue no filmmaker wants to have. Since we were wrong about what these things were going to cost, the studio is now compelled, in doing its job correctly and responsibly, to try to get us to give things up. But the dilemma of that, from their perspective, is that they're going to be spending \$100 million plus, regardless. That's a given. They've already spent a



good part of it and they're going to spend more. What do they want for that at the end of the day? Do they want a film that's a compromised,

screwed-up embarrassment? Of course not. They want a film that's something between the one that's costing way too much and the one that's a compromised, screwed-up embarrassment. But they don't know exactly how to go about that, so they look to the filmmaker, the person who knows the project most intimately, and they say, 'What do you think you can give up?' They were suggesting things like the engine room and the boiler room- which would have eviscerated a couple of major sequences. So I was not prepared to give those up, even though it made sense on paper, because I believe that my responsibility to the people who put up the money is to make a good film. I must be the warrior for the film, the guardian of the film. That's what they hire me for- that's my role. The studio's role is to get the very best possible film for the very least amount of money. That's a slightly different goal, though it's related to mine, because at some level we both want the best film. They want it for the least amount of money- and because I have a profit participation in the film, I also have a goal to do it as cheaply as possible. So in theory, we're in agreement every step of the way. In practice, it doesn't always work out that way."

In early May- while dialogue relating to completion costs and release dates was still underway- Jim Cameron voluntarily signed over his Titanic directing and producing fee, as well as his profit participation, to the studio. Although, no dollar amount was revealed, it can be assumed that the gesture cost the filmmaker upwards of eight figures. "Titanic was already way over budget," Cameron explained, "and the cost was still rising. Fox was understandably distressed.

But the solutions they saw in terms of how to control costs, I did not believe would work. I knew that more intimately than they did, and I felt that I had to give them a tangible demonstration of it- especially since we were still racing for a summer release and they were equivocating in the areas of effects and postproduction where money had to be spent to meet major milestones. My relationship with Fox is one that I value, and I wanted the people at that studio, those at the highest echelon, to know that the situation we were in at that moment was not one of design, that I was not like other producers out there who lowball the budget and then drive it up to whatever the studio will bear during production. That was not the intention- and the only way I could demonstrate that was to show that it was hurting me as much as it was hurting them. I believe it was the ethically correct thing to do."

With the cost of the picture diminished by the return of his compensation, Cameron managed to complete Titanic for slightly less than the \$200 million most commonly projected by industry watchdogs. Whether that makes it the most expensive Hollywood movie of all time- as it has been branded almost from the outset- is subject to debate. Adjusted for inflation, the infamous

Most who survive the ship's sinking succumb to the freezing waters in scenes filmed within a shallow, heated stage tank.



Shots photographed in the indoor tank would later be enhanced with stars and vaporized breath.

Cleopatra still seems to hold that dubious title. It may not even be the most expensive film of 1997. Reliable sources contend that Batman & Robin lumbered in at \$225 million- its manifold excesses obscured by a more media-proof studio.

Cameron cares little about such distinctions- but he does have a parting thought for his critics in the fourth estate. "It galls me that the media glommed onto Titanic as being symptomatic of a sick Hollywood- that it was somehow typical of a trend toward spending way too much on disaster epics and action films. Nothing could be further from the truth. Titanic is not a disaster epic or an action film. Call it a love story or a \$190 million art film, whatever, but Titanic is not a road map to the future. It's meant to be a singular picture. The media is constantly whining about how big studio blockbusters are all the same- all formula pictures or sequels or comic book movies, all designed to create a franchise or sell slurpy cups or bendable action figures. So we do a movie that has no franchise potential whatsoever, no merchandising potential, that's about people and emotions, and not one mindless action sequence after another- and we get pilloried for being typical of what's wrong with Hollywood. All we did was try to make a beautiful movie. Titanic cost a lot more than we thought it would, and I don't know at the end of the day if it will be successful relative to its cost. But to be honest, I doubt that Fox ever saw this as a particularly commercial film. I believe they agreed to do it because it was what I wanted to do and because they knew we'll be doing other things in the future that'll be more commercial. If they break even, I think they'll be happy. So Fox is not going to be making a lot of money off this picture. The actors aren't making that much either, other than whatever cachet comes their way in terms of industry standing. As for me, I'm not making anything on it- essentially it's been a three-year pro bono job. So nobody's going to get rich. At this point Titanic is a gift- a gift to the world."

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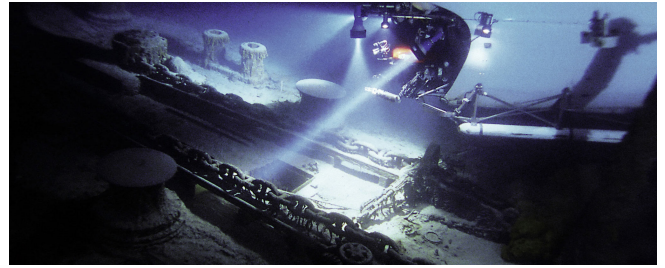
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SHIP OF DREAMS

ARTICLE BY DON SHAY

No one ever accused James Cameron of making easy films. His canvas is invariably large. Logistics are complex and schedules are long, and his cast and crew are often tested as severely as his movies' protagonists. Cameron thinks nothing of shooting for weeks, even months, in ice-cold abandoned power stations and steel mills, in wetsuits and scuba gear under fifty feet of water, or in warplanes perched atop wind-blown skyscrapers. And the demands on his visual effects crews are no less intense— especially as he seems to like writing images into his scripts that are achievable only via cutting-edge technologies not yet developed. Cameron's full-throttle commitment to his movies— and his insistence upon nothing less from anyone working on them— is legend in Hollywood, and his take-no-prisoners approach to the filmmaking process has earned him a sizable faction of vocal detractors. But those same traits have won him a cadre of staunch loyalists who relish the challenge and have served with him on numerous productions. Many of the same names appear over and over on Jim Cameron films. He likes it that way.

Small wonder, then, that visual effects supervisor Robert Legato— an Academy Award nominee for his work on Apollo 13— had some concerns about stepping into the shoes left unfilled by Cameron regular John Bruno, who departed Titanic after five months of preproduction to direct his own first feature. "When Jim first talked to me about Titanic," recalled Legato, "it was still up in the air as to whether John was going to do it. Obviously, if his film at Universal came through, he would do that; if not, he would stay on and



A deep-sea submersible illuminates the remains of the Titanic, lying under two and a half miles of water on the floor of the North Atlantic, in footage of the actual wreck photographed by James Cameron for use in his epic film Titanic. For modern-day scenes bracketing his period narrative of ill-fated love aboard the doomed luxury liner, the filmmaker, on a Russian research vessel chartered by the production, made twelve dives on the eighty-five-year-old wreck. Special deep submergence gear— including a custom-built two-perf camera— was required for the venture.



Hampered by poor visibility during the dives, Cameron would rely on models for wide views of the wreck and for shots in which more than one submersible was needed. Closer views and single-sub scenes generally featured the actual Titanic. Much of the film's miniature and digital work was provided by Digital Domain under visual effects supervisor Robert Legato.

do Titanic with Jim. Anticipating that he might need a backup, Jim asked me if I would consider doing it. I hesitated a bit. Working with Jim Cameron was an exciting prospect, but I was frankly a little nervous about it. Jim and John have worked together on several pictures. They are both artists, and they can draw and get their ideas on paper. I can't do that. I have to photograph something. Plus I've never worked for a director who's as knowledgeable about effects as Jim is, and as specific and insistent about what he wants. I've always worked for people who know considerably less about the subject than I do- people who depend on me to come up with ideas and ways of doing things. I wasn't sure how much of that there'd be with Jim. So I waffled a bit and told him about my concerns- but he liked Apollo a lot and seemed to want me, so that was about the extent of it. Virus came through for John, and I was on Titanic."

From his first reading of the script, Legato realized that the intimate epic envisioned by Cameron would require a unique approach when it came to realizing full views of the Titanic at sea. "Ideally," observed Legato, "the way to get the shots Jim obviously had in mind when he was writing the script would be to build a full-size Titanic, load it up with a couple thousand extras, haul it out to sea and photograph it from a helicopter. But even this film, as big as it was, would not support that kind of expense." Clearly some sort of miniature work was in order, but what Legato found lacking in oceanic films of the past was that they consisted principally of actors performing on shipboard sets intercut with occasional full-ship miniature shots. "What separates these films from what you'd really like to see- even *A Night to Remember*, credible as it was for the time it was made- was that the model shots were always very wide. They had to be. If they were any closer, it would have been obvious that there were no people. My feeling was: 'Why redo the Titanic story if we're not going to do it any better than that? It's so limiting.' Jim uses lots of big camera moves; and if he were out on the ocean with a real ship, he'd be all over that thing with a helicopter and a Wescam. I figured it was up to us to give him that same capability with miniatures."

Right from the start, Legato envisioned peopling the Titanic with scores, perhaps hundreds, of computer generated passengers animated in ultra-lifelike manner through the application of motion capture technology. In theory and practice, motion capture entails recording, by one of several proven means, the movements of live performers, distilling those movements into pure digital components, and utilizing the data thus derived to drive computer generated figures. Although most of the major effects houses have invested heavily in the nascent technology- long considered a potential boon to the art of computer animation- it has, to date, been used only sparingly, never quite reaching its full potential.

Aside from the near-perfect replication of movement, the beauty of motion capture is that once an action has been translated into digital form, it can be applied to any number of digital characters and photographed from any conceivable angle. "The traditional thing- which we did on *Apollo*- is to shoot people on a greenscreen stage, shrink them down and place them in the shots," remarked Legato, "The limitation there is with three-dimensional movement- which, of course, is Jim Cameron's trademark. Many of the storyboards Jim and John had developed indicated big sweeping moves over the Titanic, with lots of people on deck. To do something like that using traditional greenscreen, you would have to accomplish the actual move on stage and track it to your model photography- clearly impossible as it would require a move hundreds of

feet long and a hundred feet in the air. Rather than try to eliminate those shots or pare them down, however, I decided to embrace them. These would be our showcase images, and motion capture would be the way to get them. It had to be photorealistic and the technology was not quite there yet- but I thought it was getting close."

Of comparable concern to Legato were the ocean surfaces upon which the Titanic would cruise. "The most obvious approach would have been to build a really big model and actually put it in water," stated Legato, "which is something that was done on *The Abyss* with great success, so I imagine Jim would have been comfortable with it. Personally, though, I had a problem with that approach. You can get short shots where it looks pretty good- three or four seconds maybe- but it's very hard to sustain without getting that slow-motion look to the water that sort of scales, but doesn't really. I hate that. I knew that for some of these big, grand views of the Titanic, we were going to have shots that were thirty or forty seconds long; and I had doubts that we would be able to pull them off- to my satisfaction or Jim's- using models on water. The other way it could be done would have been to photograph the model on stage and comp it into actual ocean plates shot from a helicopter. That would have required, among other things, a massive tracking effort. On *Apollo* we tracked a helicopter move, and it took us twelve weeks. *Titanic* had forty of those twelve-week shots- and we had nowhere near that kind of a schedule."

At the time these issues were being addressed, *Waterworld* was garnering attention within the effects community for a sequence in which its rustbucket *Exxon Valdez*- a full-size deck set built on dry land- was put to sea on water that was entirely computer generated. "I think *Waterworld* demonstrated that CG water was on the cusp of starting to work," remarked Legato. "If we could take it to the next level, I felt it might afford us complete control over our water plates, which was something I believed was essential for *Titanic*. The water did not need to be perfect in an absolute sense, only convincing enough so that people would accept it as real. After all, who was going to be looking at the water anyway? Unless we screwed up big time, people would be looking at the ship. I got some resistance at first; but we did a couple of early film tests that were very convincing. We sent one over to Lightstorm; and the production manager, who had just been hired, asked, 'When did we shoot this?' He bought it completely. At that point we decided to go for it."

Although Digital Domain had been involved peripherally in the *Titanic* preproduction effort for the better part of a year, work commenced at a



Motion control operator James Rider and his crew prepare to photograph a twentieth-scale replica of the forward section of the *Titanic* wreck, built in a hangar at the former Hughes Aircraft facility in Playa Vista. The ship model and surrounding ocean floor, configured and detailed to intercut with footage of the real submerged wreck, were

fever pitch once the project received its formal greenlight from Twentieth Century Fox in May 1996. Recruited to shepherd the projected 150 effects shots through the facility were visual effects producer Crystal Dowd, visual effects line producer Cari Thomas and digital effects producer Karen Murphy. High on the list of immediate priorities was securing a workspace large enough to accommodate a prodigious model building effort and the motion control photography attendant thereto. Selected for the purpose was a hangar at the former Hughes Aircraft plant in Playa Vista that had been used a bit on *True Lies* and *T2/3D*, and a great deal on films such as *Batman Forever* and *Independence Day*.

inverted and hung eight feet off the floor to facilitate filming. Same-scale submersibles- built by Brazil Fabrication & Design- were likewise inverted and affixed to driver devices on tracks parallel with the ship. Shot on a smoked stage with interactive lighting effects, the dry-for-wet underwater scenes were later enhanced with bits of floating debris. Digital compositors image-processed both the two-perf location footage and four-perf stage photography so that grain and color would be consistent throughout.

Model crew chiefs Gene Rizzardi and George Stevens- who would jointly supervise the miniature construction effort- set up shop inside the hangar in June and immediately set to work on a twentieth-scale replica of the Titanic that would serve as the principal motion control model. "For a while," commented Stevens, "we were getting plans and drawings from Lightstorm just about every day- including copies of the original ship's blueprints. We were also given a large stack of photos, many of them from Ken Marschall's personal collection. Once we figured out the approach we wanted to take, Gene contacted a naval architect he knew out of Santa Barbara, and through him we hired a couple of boatwrights- Bill Canty and Russell Peters- who brought in a small crew of mid-level hammer-swingers to help build the hull. Even though the model would never see water, we felt that experienced boatbuilders would be the best ones to duplicate the Titanic's sheer- which is the banana-like bend that most ships have- plus all the little twists and curves of the hull."

To facilitate assembly, the hull was built upside-down. With blueprints enlarged to scale serving as patterns, cross sections of the vessel were cut from twelve-ply Baltic birch plywood- noted for its strength and stability- then positioned along two strings pulled taut to represent the waterline, the only straight line on the ship. Carefully aligned and shimmed into place, the cross sections were then connected with wooden stringers and skinned with two layers of eighth-inch-thick luan- a flexible wood applied in strips- which was stapled down and epoxied. A smooth surface coating of fiberglass was applied overall for added strength. The forty-four-foot construct was then turned rightside-up and fitted with a welded steel armature- built by Tom Woessner- that had special key points enabling the ship to be split in half.

While the hull was being built, teams of modelmakers, organized by floor lead Gordon Forkert, were busy fabricating deck structures and shipboard artifacts. "With the schedule we had," remarked Stevens, "there was no way we could wait until the hull was finished. We had to start building on everything else and hope it all came together at the end. One of the most critical things was duplicating the sheer line. Since the entire ship has a heavy sheer- most noticeable in the bow- we couldn't build on a flat surface. So we took the sheer line off the blueprints and incorporated it into a table so that we could build all of our decks on top and be reasonably

assured that they would fit on the hull. Happily- surprisingly even- we had to do very little rebuilding."

Decking on the model was laminated plywood, laser-scribed to create the impression of individual planks. Funnels were framed in plywood and skinned with sheet styrene. Deck structures were made principally of acrylic. "We had separate teams working deck by deck," noted Stevens. "We had a team working on the forecastle and the poop deck, which were built as units. Other teams were assigned to the A-deck promenade and the two well decks- and then all the other decks in between. The boat deck- with all of its ventilators and cowlings and davits and lifeboats- required the greatest amount of work. We had neither the time nor the manpower to do it all, so we enlisted Vision Crew to build the lifeboats and davits. They also did ventilators and electric cranes and a few other things- and did a very good job for us. It was great to be able to just receive parts and stick them on the ship."

Vision Crew was also engaged to produce more than a thousand brass portholes in four sizes, complete with plastic windows, that could be pushed quite easily into hull holes drilled with precision and backlit with neon. Dimensional Presentations International, a firm specializing in architectural model parts, machined thousands of brass railing stanchions which were installed on the ship and connected with fine wire. Lasers Edge, another outside vendor, provided laser-cutting services on some of the model pieces that were too big for Digital Domain's in-house Lasercamm. "We had to cut a lot of windows into the deck walls, some of which were quite large pieces," recalled Stevens. "The tricky thing was that every window had to be perpendicular to the water. But since the boat has a sheer, that meant that every window was at a slightly different angle. That sort of thing can drive you crazy. Fortunately, our vendor was able to take the blueprints we had from Harland and Wolff, scan them into their computer, and then cut the windows precisely as indicated."

Despite valuable outside contributions, most of the toil fell on the shoulders of the fifty modelmakers working directly for Digital Domain. Detailing alone- some of it almost subliminal- was especially taxing. Individual hull plates- made of Sintra, a PVC plastic which is foamed to make it less dense- had to be fitted and affixed to surfaces that were seldom strictly flat. And then there were the rivets. Posted prominently in the model shop was a quotation attributed to Thomas Andrews- builder of the Titanic- asserting that it takes three million rivets to make a truly fine ship. Fortunately for the model builders, a good many rivets were buried out of sight within the bowels of the Titanic, because the passion for accuracy permeating the Cameron production dictated that those visible from without would be reproduced on the model.

"Originally, I was scared to death of all the rivets," admitted Stevens, "and I knew Gene was, too. The usual things you would do- like making patterns and casting them right into surfaces that are repeatable- would not often work here because the rivets on the Titanic reflected the sheer and thus did not run in straight lines. So we knew that most of them would have to be done by hand. One way of doing that is with paint or glue dots- and we did some of that- but Rob Legato felt that in a lot of the areas the camera would be too close on the model to get by with that approach. The alternative was to insert individual little brads or pins- and that's what we did. There's somewhere around 100,000 hand-applied rivets on the ship. It took a week to

drill all the holes, using flexible templates made from our Harland and Wolff plans, and then another two weeks for eight people to put all the rivets in. It was a daunting task, but it went quite fast considering.”

Also on the docket was another twentieth-scale model of the Titanic, this one replicating the vessel as it looks today after lying for more than eighty-five years under two miles of water on the floor of the North Atlantic. “We started on the big 1912 model because that was the one that was supposed to be delivered first,” stated Stevens, “but the wreck was being built at the same time. As soon as the boatbuilders finished the big hull, they went on and built the forward section of the wreck.” Only the front half of the wreck, remarkably intact, would be featured in the movie. The rear half, which sustained massive damage during its plunge to the bottom, lay a third of a mile away in inky waters and would not be seen. “As we built parts for the big ship, we made duplicates for use on the wreck. It was both challenging and fun trying to duplicate the Titanic as it is today. We had a lot of video footage from Jim- and from Al Giddings who dove on the wreck a year or two prior- and we had a bunch of people just studying all of this video and figuring out where everything was and what it looked like. The odd thing is that there are items on the ship that look like they were made yesterday, and then there are other things that are completely rusted away. It was impossible to reconstruct the entire wreck from the video, but the people we had working on it were very good at taking what there was on the video and extending it so that it had the correct feel.”



Modelmaker Gerry McClung and lead modelmaker Gordon Forkert assemble a twenty-five-foot study model of the Titanic used by Cameron to previsualize live-action and miniature ship shots during the preproduction phase.

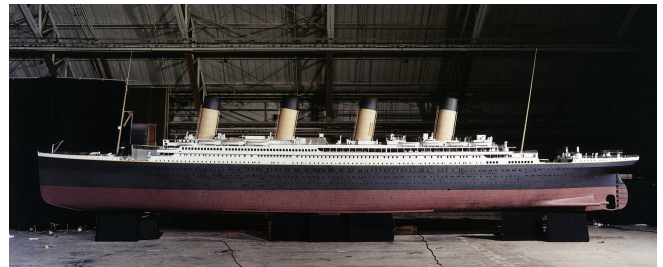
When the front half of the Titanic struck bottom, the bow drove into the ocean floor and momentum snapped the ship at the forward well deck, producing a bend in the hull directly below the bridge. Working from existing reference materials- including a painting by Ken Marschall- the modelmakers duplicated the impact damage. "The reference we had indicated two bends at about seven degrees each," commented Stevens, "and we built those into our model. Jim was in and out for a couple of weeks when we were nearing the finish stage; and he looked at it, and said: 'No, no. It's not like that. It's more bent.' When he was doing his dives, he had flown up on the ship and really studied it, doing all the math, and he said that it needed to be bent another seven degrees or so. He's the boss, so we rebent the ship. To me it looked funny at first; but the more I studied it and looked at the video, the more I realized he was right. It really is bent that much."

Once the wreck was properly configured, it had to be detailed with equal conviction. "Rob was very worried about how we were going to make the wreck look rusty," recalled Stevens, "because rust is one of those things that's hard to do in scale. As it turned out, we discovered a paint called Instant Iron that helped a lot. Basically you spray it on and it rusts." A bit more ingenuity was required to reproduce the stalactitic fingers of rust- dubbed 'rusticles' by Robert Ballard- that now eerily drape the aged wreck. "While we were detailing the wreck, I got a call from Crystal Dowd. 'You know, George,' she said, 'I don't mind buying coffee for the crew, but why are we buying snacks for them?' And I said, 'Oh, you mean the Cheetos?' She said, 'Well, yeah.' Then I said, 'What about the wheat germ and bran flakes?' And she went, 'Oh, no.' We were using all of that on the wreck. It turned out that Cheetos look very much like rusticles. Just spray them with ruddy brown primer and add a little bran flakes for texture, and the similarity is really quite amazing. Other rusticles- especially those on the side of the ship- were hand-applied with a cake froster."

In addition to rusticles, the ship was covered with an accumulation of fine silt. "At first we thought, 'Well, how hard can it be to put silt on it?'" remarked Stevens. "Then we realized that the model was going to be filmed upside-down, so the silt had to be glued on. Brian Ripley and Ted Van Doorn, two of our lead painters, came up with the idea of mixing lightweight spackling paste with pigment and a little bit of glue, putting it in a house-paint sprayer, and just dusting it into the air and letting it settle. It worked beautifully. Those were the kinds of inventive



For shots of the full ship in its pristine state, a twentieth-scale model was constructed from original blueprints and photos of the actual vessel. Experienced boatwrights were engaged to build the massive hull- fitted with a steel armature that enabled the model to be split in half- while a team of fifty modelmakers attended to the deck structures and other detailing. Garrick Gilham affixes hull plating to the port side.



The forty-four- foot Titanic replica took five months to complete.

solutions that made the wreck model my favorite. The big boat, when it was all done, was an amazing achievement- but building it was frustrating because it was just parts after parts after parts. With the wreck we could be more creative.”

Representing only half of the Titanic, and with detailing that was less exacting, the wreck model was actually finished several weeks ahead of its pristine counterpart, despite a later start. The forty-four-foot beauty ship sharing hangar space nearby required five exhausting months to complete- a full month longer than allocated for the project. “We were late and over-budget by a fair amount,” admitted Stevens. “I think it was just that nobody really anticipated all that was involved in making a model of this complexity. It seemed fairly straightforward, but it was not. It was like building a dollhouse- a simple dollhouse- and suddenly realizing that there are fifty doorknobs scattered throughout that are all going to take extra time. This whole project was like that. The concept was to do an A-level model on both ends- where the key action was going to be- and in the middle, somewhat less than that. But everywhere we tried to cut corners, the response was, ‘Well, we’re going to be tight on that.’ And to be honest, when you have a whole model crew out on the floor, it’s hard to restrain certain people and let others go. No one wants to do a half-assed job while the guy next to him is doing really great work- that’s simply not in the nature of modelmakers. So, for whatever reasons, we basically ended up with an A-level model over forty-four feet.”

Modelmaking of a different sort altogether was also underway at the main Digital Domain studio in Venice. There a computer generated replica of the Titanic was being fabricated by the newly-formed ‘NT’ unit- so named because of its reliance on low-end computers juiced with high-speed Digital Equipment Corporation Alpha processors and running the Microsoft Windows NT operating system. Like most other major effects houses, Digital Domain has, from its inception, invested heavily in high-end Silicon Graphics workstations, long the industry standard for producing state-of-the-art digital imagery. But in recent years, with upstart companies such as Amblin Imaging and Foundation Imaging using supercharged personal computers to create impressive, budget-friendly effects for television shows such as seaQuest DSV and Babylon 5, even the best capitalized competition has begun to take note. Not every effects problem, it appears, requires a Mercedes-Benz solution; some can be handled quite adequately with a Volkswagen. To introduce some low-end capability into the Digital Domain palette, digital artists Richard Payne and Fred Tepper- both formerly of Amblin Imaging- were hired in April 1996 to be part of a group charged with establishing an NT unit within the company.

“When we started,” said Tepper, “there wasn’t much to do for the first few weeks. We were new and just getting set up, and no one had anything specific for us. We knew that Titanic was in the works and we felt sure that we could do a digital ship good enough to be used in the show; but for a while there was question as to whether anyone wanted to go that route. Scott Ross was our main advocate- he believed we could do it- but it was



Tugboats ease the Titanic away from the Southampton dock as the great ship prepares to embark on her maiden voyage. Fabricated entirely in postproduction, the scene featured the model

ship, portrayed by computer-generated water and wind. According to the *Guardian*’s special 60-graphic film *Rossini*, in order to help water take age and the film’s model uses, for instance, wind-tunnel data to make the water flow over the ship’s rails were either greenscreened or computer-generated. The film’s water was edited with extra as a basis, while crowds below were predominantly greenscreened. I think digitally manipulated them many times over to provide the illusion of a bustling imagery derived from still photographs enhanced with matte painting elements.

htWave 3D, a formidable modeling and

and in recent years because of its simplicity of

to utilize it. The model had not been weathered yet- it was basically pine, laid out in boards- so I had to guess at what the final paint job would look like. I ended up repainting everything four or five times, for a variety of reasons, because any change made to the physical model had to be made on ours as well. Luckily, Photoshop has nice layering capabilities, so I was able to make the deck itself one layer, the dirt on it another layer, and so on.”

Although the NT ship surpassed expectations, only three shots in the film would feature it exclusively- all distant views from the air to establish that the Titanic, enormous and formidable as it was by human reckoning, was nonetheless dwarfed to insignificance by the immensity of the ocean upon which it coursed. It would also be seen- in deliberate low-resolution form- during the modern-day segment in which Brock Lovett and members of his salvage team show Old Rose a clinical computer simulation of what happened to the Titanic in her final hours. Less flashy- but of greater overall import- was its use as a template for tracking camera moves and locking live and digital people onto both miniature and full-size sets. Most important of all, the digital ship would play a vital role in nearly fifty shots, serving as the mechanism by which the Rosarito ship could be extended beyond its physical limitations. While the massive set would represent the Titanic nearly in its entirety, certain areas, such as the forecastle and the entire port-side hull, would be omitted for economy. For scenes requiring the inclusion of these and other areas beyond the camera’s reach, high-resolution renders of sections of the NT ship would be incorporated into the live-action photography to effectively complete the set.

Disappointed, no doubt, that the big beauty shots eluded them, members of the NT team nonetheless welcomed any and all Titanic assignments with bullish enthusiasm. “Up until now, the perception has been that LightWave is fine for games and television production,” remarked Payne, “but for high-quality feature work you need Softimage and Alias and the other Silicon Graphics things. I think Titanic will prove that LightWave can stand proud with the big boys. There’s no arguing that SGI and everything tied to it are at the top of the food chain. They were here before us and have proven themselves- they’re the T-rexes. But we like to think of ourselves as raptors, smaller and faster and nipping at their heels.”



First Officer Murdoch and Captain Smith observe from the bridge as the Titanic gets underway. Filmed on a greenscreen set, actors Ewan Stewart and Bernard Hill were composited over plate photography of the model, afloat on a sea of shimmering pixels. Motion capture was used to animate computer generated people on the deck below.

The T-rexes were not about to be overrun, however. Forging ahead on the Silicon Graphics side of the house was a multi-pronged task force being overseen jointly by digital effects supervisors Mark Lasoff and Judith Crow. "At the beginning," commented Crow, "Mark and I worked quite closely together on R&D and developing a strategy for the whole show. We determined that there were five main areas of concern. First was the motion capture and character animation, plus all of the issues associated with rendering people and placing them on the ship. Second was everything relating to the digital ocean- the software to produce it and the means by which to make it work within the pipeline. Third was data integration- taking motion control data and tracking non-motion-control shots, then setting up a system so that all of this data could be handed off to everyone on the show. That was very important. Fourth was the digital ship- which was done by our NT team as an offshoot separate from everything else that was going on. And finally there was a catch-all 'paraphernalia' category for things like smoke, ice, birds, spray elements, skies, stars, horizon glows- anything digital that didn't fit anywhere else." Because of the disproportionate amount of effort involved in creating digital people, Lasoff assumed oversight of that area as his sole responsibility once the show moved into production, while Crow focused her attention more broadly on the other four components of the digital assignment.

The most critical element in the creation of digital humans was the replication of human motion. No other aspect was as apt to make or break the illusion. "We knew, pretty much from the start, that we were going to have to populate the deck of the Titanic with digital humans," stated motion capture supervisor André Bustanoby, "and that they had to look absolutely real so it would not be apparent that there was an effect happening. Not only did they have to look real, they had to look



A majestic reveal of the ship slicing through the ocean- the most elaborate visual effects shot in the film- begins on Jack Dawson and Fabrizio De Rossi at the bow. In one uninterrupted move, the camera sweeps around the two characters, past the forecandle and bridge, up through the funnels and over the boat deck, then far astern until the entire vessel is observed steaming into the distance. A greenscreen element of actors Leonardo DiCaprio and Danny Nucci was filmed on a small set piece with a move matched to the camera's motion control passage over the model ship. Animators and digital compositors later morphed from the real actors to computer generated clones, then scattered hundreds of digital passengers and crew about the various decks during the overflight.



real in context. In other words, they had to be lit with the same lighting that was on the ship, they had to have costumes that moved with conviction and they had to interact with one another. Most

especially, the bar was really high in terms of the fidelity of the motion because each character had to represent a societal cross section and also communicate a little story. Early on, we did a fair amount of testing. We started with just two characters, a female and a male, both in period costume. Normally when you do motion capture you have the subject wear a bodysuit covered with markers so that arm and leg movements can be readily isolated. But that doesn't take into account whatever costumes the characters might be wearing. Since women of the time wore long, flowing dresses and men wore coats and hats, Rob Legato and one of our lead modelers, Shawna Olwen, came up with the idea of putting markers not only on the arms and legs, but also on the costumes. That way we could capture the dynamics of the fabrics. And it worked. It didn't matter that we couldn't see the woman's legs if she was in a long dress, because they were being inferred by the markers on the fabric. The subtle motion derived from the costumes just added another layer of complexity that we didn't have to calculate. It was physics for free. We did a quick render of that first test, showed it to Jim and Rob, and they said, 'All right, this is going to work.'"

Composited onto the model, Jack and Fabrizio survey the digital ocean from their breathtaking vantage point.

After much additional testing, motion capture commenced in earnest in November. Recording of the data took place at House of Moves, a dedicated motion capture studio located in Venice, only a block away from Digital Domain. There, over a period of three or four days, Legato directed thirty costumed extras- most of them Digital Domain employees- through a variety of generic and specific activities considered appropriate to the various classes of people on board the Titanic. These real-world performances- recorded and processed by the facility's Oxford Metrics Vicon motion capture system- would later be used to drive the actions of as many as five hundred digital passengers in some shots.

Encircled by seven high-resolution video cameras to record their every movement from all directions, the surrogate ship passengers were arranged singly or in pairs and put through their paces. Depending upon the style of the period attire being worn, each individual was covered with between fifty and sixty-eight motion capture markers- significantly more than the thirty considered sufficient for a bodysuited figure. "The markers we used were little plastic balls," commented Bustanoby, "about three-quarters of an inch in diameter and covered with a retroreflective material. Depending on the costumes- some of which were antiques and very delicate- we attached them using either pins or velcro. With seven cameras arrayed around the performance area- each shooting at 60 or 120 frames per second, depending on whether the action was relaxed or frenetic- at least three or four would be photographing any given marker at any given time, even when more than one person was being recorded. The markers are illuminated with infrared light emitted from the cameras, so ambient light has little effect on the image- essentially what's being recorded is a frame full of white dots on black. Calibration is always critical because the computer takes the constituent two-dimensional views of these cameras and triangulates the location of each dot. A lot of predictive algorithms then come into play in determining dot trajectories from frame to frame."

Getting human performances out of human performers was not always as simple a task as it might seem. “A lot of people who get into motion capture are so captivated by the notion of it that they pay little regard to the type of motion they can capture,” noted Legato. “As a result, much of what you see is big and splashy- motion capture strutting its stuff- which can certainly be cool, but that’s not what I was after. What I wanted was subtlety and natural movement- nothing big and broad. And that, surprisingly enough, was a hard thing to get- at least with nonactors. You can’t just put anyone in a suit and have him walk around. Chances are it’ll look stilted and phony. Simple as it may seem, there’s a real art form to moving, and acting with your hands and your arms and your body, and most people who aren’t trained actors have trouble with it. I know that, because I’ve done a lot of second-unit directing where you’re always pulling someone in to push a button, or something, and it’s like: ‘What are you doing? I want it lifelike!’ So I had to really work with people on their performances, even though they were just doing everyday things. These were fellow employees- and I had no wish to insult anyone- but some of them just couldn’t do it. So I had to capitalize on the ones who could. T. Paul Miller- head of the finance department here- is on just about every deck of the ship, doing everything, because he happened to move pretty well. Others, I’m afraid, aren’t going to find themselves up there on the screen.”

Though most of the digital characters would be strolling on deck or conversing in small groups- activities that could be replicated many times over without raising audience suspicions that something was amiss- others were given featured choreography that could rarely be used more than once. “I approached the motion capture like I would if I were the director doing the scenes for real,” said Legato. “On a bald stage, with nothing around you, not a lot of ideas are going to come. Ideas come from having a real environment. If we wanted some activity on the poop deck, for example, we would build a little set- or at least a semblance of a set- so we would have something physical to work with. Perhaps it would be just a couple of benches, or something representing a wall or a capstan. Then I had a computer plate of the ship that we double-exposed over a video view of the stage. And with that I was able to direct some specific action: ‘Okay, if I were a kid, I would run behind this and go over here.’ We have kids chasing each other around a bench and others bouncing a ball on deck. We have a lady picking up her baby. Two guys in third class are horsing around- one grabbing the other like he’s going to



First we did the move on the ship to make sure we had it exactly the way Jim wanted it. From there we determined that what we needed, essentially, was a circular move around the actors.



First we did the move on the ship to make sure we had it exactly the way Jim wanted it. From there

push him overboard. None of this is meant to be scene-stealing. The idea was that when you look at the ship and all the people on it, not everyone is walking back and forth like a robot- although we did have a lot of generic crosses and such. Even on those, however, we added little things to spice them up- a nod or a tip of the hat when people passed each other, for example, some sort of interaction. Oddly enough, the more work we did and the more technology we applied, the less it looked like we did any work at all- which is exactly as it should have looked. The more detail you put in, the more real everything becomes.”

Though impressive in its ability to replicate movement, the motion capture process is far from perfect. A considerable amount of cleanup is still required to fill in the blanks, particularly in instances where crucial markers have been obscured from camera view or when the computer confuses the trajectory of one marker with that of another. “Just getting the data organized was a very big deal,” affirmed Mark Lasoff. “The motion capture software is generally good at recognizing the markers over time; but if one marker passes near another one, as often happens, the system may swap them- which would obviously result in a false trajectory. Before the data was delivered to us, House of Moves did a certain level of cleanup, including taking care of marker continuity- which meant that if there were swapping-ball problems, they would connect the dots, so to speak. The data would then go to our motion capture department, where André would do the second half of the cleanup process, which entailed converting the data to 24 frames per second and filtering out noise or chatter if the moves were not perfectly smooth. He would also assign marker locations to joints and wardrobe control points for each digital character. From there, it would all be sent to an animator who would envelope the wardrobe onto the character. At that point, we would have a full walking skeleton with wardrobe information.”

While the motion capture was intended to limit the amount of hands-on animation required to put digital passengers on the deck of the Titanic, there was still plenty of work for the animators to do before these virtual characters were ready for their screen debuts. “In doing the motion capture,” remarked Lasoff, “we found that we got a lot of phenomenally subtle human movement that would have been very, very difficult for an animator to incorporate into a character. But the price you pay for that level of fidelity is that it’s very difficult and very time-consuming to alter whatever has been captured. Any fixes require serious animation. The beauty and the curse of motion capture is that you have data in every frame. To change it at all, you have to go in and strip out the recorded data and replace it with animation. In some cases we would have to do this because of a miscalculation on our part. For instance, we had a lot of scenes of people standing at the railings. On the Titanic, rail heights were different in different areas of the ship. Some were three-foot-nine, others were three-foot-six- a few of the interior rails were three feet. We only captured at one of those heights- an error in our thinking- so we

we determined that what we needed, essentially, was a circular move around the actors. James Earl Ray, the movie just digitized motion and fired it out to the film that we needed, essentially, was a circular move around the actors. Paul Miller. Motion capture- used to create a library of both generic and specific performances- would prove invaluable in creating lifelike character animation for hundreds of digital extras seen strolling the decks of the miniature Titanic. Unlike traditional motion capture- in which performers are dressed in bodysuits with principal axes of movement delineated by trackable markers- the Titanic performers were dressed in period wardrobe, with expanded marker sets affixed to clothing to provide even more comprehensive movement data.

had to alter the animation of our characters' arms to work at various rail heights along the Titanic. That meant stripping out a lot of the motion capture data and key-framing the arm movements to fit. But even scenes with no miscalculations required a lot of work. I would estimate that the basic motion capture got us about fifty to seventy percent of the way, very quickly, after cleanup. We would do a quick-shade render and look at it, and say: 'Yup. That's a human being all right- but look at those glitches.' A head might be cocked awkwardly or a foot might be twisted like an invalid's- or there might be jitter in the arms. Motion capture is, after all, an imperfect science. Perfecting it involved removing all the twitches and errors, or smoothing them out, or fixing them, or just going in there and ripping out data and replacing it with key-frame. Whatever the problems, the fixes were invariably painstaking and labor intensive and took real hardcore animation- and we found that only our most talented animators were up to the task."

As important as the digital characters to the verisimilitude of the Titanic model shots would be the ocean surfaces upon which the ship would sail. Once the determination was made that computer generated water was the medium most likely to produce results that were believable over the long term, Lasoff and Crow launched an R&D effort to select a specific methodology. "We knew that the digital characters were going to be a huge challenge," observed Crow. "Coming in, that was probably our biggest fear. A close second- and occasionally topping it- was the issue of the water. Ocean water is traditionally very hard to do- compounded by the fact that most people have a pretty good sense of what it needs to look like to appear real. Early on, we looked at whether we were going to be able to develop in-house software to create our water- which we would very much like to have done- or build on software that was already existing. With the time frame we had, and knowing all the other things that would have to be developed in-house, we decided it would be best to look outside the company."

The digital water plates in Waterworld had been produced utilizing highly specialized software developed by Areté Image Software. "We tested the Areté software and found it quite extraordinary at simulating ocean surfaces and the effect that different wind and atmospheric conditions had on them," said Crow. "But at the time, there were lots of things we were going to need that had not yet been incorporated into the software. For example, Areté had not yet dealt, to any great extent, with the interaction between objects and water. There was really no way to generate a matte so you could show where an object sat in water. There was no mechanism for dealing with reflections. And there was no way of defining the sky, aside from their default sky, which was cloudless and sort of blah. None of those things mattered on Waterworld- where the scenes took place on the ship deck and you just looked out onto an expanse of water- but they were essential to us. So we went into a long development phase with Areté, where we would define what parameters we were going to need and how we needed to be able to control them, and they would write the implementing software. Then we wrote our own front end. The Areté software was completely text-based- just long text files defining each frame- so we fashioned a custom interface, using Prisms software, that would allow us to set up a scene fairly simply, then dump out the necessary files to render the ocean. Otherwise there would be a full-week learning curve before any artist we brought in could even begin to render a plate with water in

it.” In all, about four months were required to customize the Areté software to meet the technical and aesthetic requirements of Titanic.

The film opens in the present as two deep-sea submersibles from the research vessel Akademik Keldysh descend through two and a half miles of North Atlantic ocean toward the final resting place of the Titanic. With high-intensity spotlights probing the silt-covered remains, they proceed to a vast rupture in the deck, over what had once been the grand staircase, and release a remotely operated vehicle, equipped with stereo video cameras and manipulator arms, that drops into the wreck and snakes its way through corridors and passageways en route to a very particular area of the ship.



To avoid problems of scale that often occur when models are photographed on real water, the decision was made to use computer generated water for nearly all shots of the Titanic at sea. For authentic wake imagery that could be mapped onto the digital ocean, Rob Legato and James Cameron took to the waters off Southern California for a one-day shoot aboard the Lane Victory, a restored World War II merchant ship that produced bow and stern wakes similar to those of the Titanic.

To effects director of photography Erik Nash fell the task of shooting the miniature Titanic wreck and Mir submersibles- using dry-for-wet techniques- to match and be intercut with shots of the actual ship and subs filmed on the ocean floor months before by Jim Cameron. The sequence would be split, more or less evenly, between real dive footage and miniature simulations. "Basically, anything Jim could get down there, he got," related Nash, "but one of his limitations was the murkiness of the water. It was impossible to back off more than a short distance before the wreck just disappeared. So what we had to shoot were primarily wide shots- plus anything with both submarines in it. Jim had two subs at his disposal, but since one was the camera platform, that left only the other that he could actually film- and hopefully that'll be the only way to tell which stuff is his and which is ours."

Although the twentieth-scale Titanic wreck had been built by the Digital Domain crew, the like-scaled Mir submersibles- detailed to match the real ones on board the Keldysh- were constructed by veteran modelmaker Tony Meininger of Brazil Fabrication & Design. "At twentieth-scale, the subs were about the size of a football," remarked Nash. "Larger would have been better, but they needed to be in scale with the wreck because we were photographing them together on a smoked stage. We had to do that, rather than go with a multipass scenario where we could have varied the scale of our models, because visually the shots were all about interaction- the lights from one sub affecting the other sub and the wreck and the surrounding smoke- and getting that interaction would have been very difficult any other way."

The submersibles' spotlights proved problematic on all accounts. "The hardest thing was finding lights that were tiny, yet focusable and bright enough to keep it from getting absolutely absurd in terms of exposure times. What we wound up using were little triple-A-battery mini-Mag flashlights. After stripping away all the flashlight parts, leaving just the bulb and the reflector, we made housings for them that looked like the real Mir spotlights and installed them on the sub models. They worked out quite well- we could control the pattern of the beam- but flashlight bulbs can only burn so bright, so everything else had to be balanced to them. As a result, we ended up with exposure times as long as twenty to thirty seconds per frame- and that was on fast film. Then there were the times we had bulbs burn out three-quarters of the way



A camera suspended from a large crane records the churning trail left behind as the Lane Victory lays on the steam.



Jack and Rose Dewitt Bukater get acquainted on the boat deck of the Titanic in a scene photographed on the Rosarito ship set. Before digital water and sky could be added to the sweeping shot, complex articulate rotoscoping was provided by Available Light to remove the studio and adjoining property, which were clearly visible in the plate.

through a six-hour pass. It was impossible to replace the bulb and pick up where we left off, because the new bulb would never focus exactly the same way as the old one; so whenever that happened, we had to replace all the bulbs- we couldn't expect the remaining ones to last another six hours- and start over. The smoke crew had a really rough go of it. Nevertheless, motion control operator Jim Rider did a great job imparting an organic, fluid sense of motion to the entire sequence."

For a similar sequence in *The Abyss*- of deep-sea submersibles passing over a sunken nuclear submarine- Dream Quest Images had constructed a massive overhead gantry with sophisticated marionette mounts from which three model subs were flown above a sixty-foot wreck. Rob Legato rejected that approach as too expensive and ultimately too unwieldy. "We decided the best thing for us was to turn everything upside-down," explained Nash, "so instead of having the wreck on the floor and the subs up above it, we would do it the other way around." To execute this plan, both the miniature wreck and the ocean floor around it were inverted and mounted eight feet off the floor. Beneath, on parallel tracks that could be repositioned as needed, the submersibles were likewise inverted and affixed to modelmovers custom-made for the job by machinist Scott Salsa. "What we needed was a six-axis modelmover where everything was under the sub so that nothing above would become a background problem. Scott and I worked up a design- similar to a Fisher dolly- which had a dual pivoting arm that moved up and down and a pair of gear heads with a common center of rotation. Sitting on that was a plate that allowed us to have just a single vertical rod going up to the sub and mounting in the top- actually the bottom since it was upside-down- or either side or the rear. The mount was never visible on camera, so all you would see in the smoke was the rod- just a single dark band."

Although essentially a single-pass effect, a second pass was executed so that digital compositors could remove the Mir support rods. "By doing a second pass with the model attached to one of its other mounting points, the compositors could split out the support rod and replace it with whatever was behind. The mounts were precisely made, so if everything was done carefully, the sub would register to itself. It turned out, though, after doing double passes for dozens of shots- and we're talking six-hour passes here- that when it came time to put the shots together in digital, Jammie Friday, the sequence super-visor, found it was easier just to use wire removal technology, which didn't require the extra pass. We were happy for the compositors, but it would have been a nice thing to have known six months earlier." Additional sweetening was also incorporated during the compositing process. "In the real footage that Jim shot, there is always floating debris passing through the beams of light. On stage, we knew our smoke would be totally homogenous; so way back at the beginning, we shot some particle elements- just backlit fireplace ashes, thrown in the air, overcranked a little bit. After the heavy stuff falls out, what's left are very fine particles that kind of sparkle and float. What compositor Charles Meredith did was use the light beams in our pass as a luminance key to print the particles in, just where the beams were."

Throughout the stage shoot, the measure of each shot's acceptability was always how well it compared with the footage recorded by Cameron on the real *Titanic*. "Our shots had to intercut with Jim's," explained Nash. "That was the bottom line. Whenever we shot something- even if we thought it looked great- we would put it up side by side with the real thing. If it wasn't quite

there, we'd do it again. Of course, Jim was the final critic. On top of comparing it to his own footage, he was also comparing it to his memory. He has the second most time at the Titanic wreck of anyone in the world- I think only Ballard has more- and he remembers it extremely well. If anything we did wasn't on the money, he didn't hesitate to let us know."



Although night views of the ship were generally less taxing for the motion control crew than daylight ones- where slow film stock made exposure times exceedingly long- additional passes were required. Besides the basic beauty pass and matte passes, supplemental light passes for the ship's plethora of neon-lit portholes and practical incandescents also figured in the mix.



Motion control operator Chris Dawson and gaffer Victor Abbene prepare to film a quarter-scale model of the first-class lounge interior- a setting that did not warrant full-size construction since it was featured in only two shots. Greenscreen passengers were later composited into the miniature.

Even with painstaking attention to matching the look of the material Cameron had shot on the real Titanic, a considerable amount of digital work was required just to correlate, in a technical sense, the four-perf stage photography with the two-perf location photography. "We had to come up with a way of image processing the two-perf material and the four-perf material to make it all look like it was shot with the same camera on the same stock—even though it was not," related Michael Kanfer who, together with Mark Forker, supervised digital compositing on the picture. "Our biggest issues were grain matching and color balancing. The first thing we had to do was run digital extractions to take the two-perf footage and bring it into four-perf digital format. Then we took both sets of footage— the location photography and the stage photography— and removed all of the film grain in each through a degrading and proprietary filtering process we came up with. Finally we went back in and reapplied uniform film grain throughout. Equally as important was balancing color and contrast to insure that whatever we gave over to the production was going to cut properly into the movie."

Hoping to salvage a fabulous diamond pendant thought to have gone down with the Titanic, Lovett and his crew recover a safe from the suite occupied by millionaire socialite Cal Hockley who was traveling on the ship with his fiancée Rose Dewitt Bukater and her mother. Inside the safe is not the diamond, however, but a perfectly preserved drawing of a young woman posing nude— except for the pendant. The discovery is reported on television, and within hours Lovett receives a satellite call from a Rose Calvert, 101 years old, purporting to be the woman in the picture. Hoping to get a lead on the whereabouts of the diamond, Lovett arranges for the woman to be brought to the Keldysh. There— in a succession of flashbacks bridged by elegant transitions— she recounts her story.

Time-traveling into distant memories, the camera pushes past Old Rose and into a video monitor behind her. On the screen is an image of the Titanic. The camera moves in and across the bow— and as it does so, slowly, almost imperceptibly, the rusted underwater wreck transmutes into the seagoing jewel she was eighty-five years in the past, glistening and new and being boarded for her maiden voyage out of Southampton.

"That first transition to 1912 was one of our toughest shots in the film," remarked Rob Legato, "not only because it was intrinsically difficult— which it was— but because it was the first reveal of the ship and we wanted it perfect. The transformation was fairly straightforward. Erik Nash shot both the wrecked ship and the clean ship using the same motion control move, and then



For a scene in which Jack and Rose kiss while standing on the bow rail of the Titanic at sunset, Leonardo DiCaprio and Kate Winslet were photographed against greenscreen on a motion control rotating set piece that could be raised or lowered on an elevator base.

our digital team did a morph-dissolve kind of thing to transition between them. There were hundreds of people on the new ship- some of them 2-D and the rest computer generated- pretty elaborate stuff. The hardest part of the shot, however, was that almost nothing in it was real- which was also true of our other shots in the sequence." It had not been planned that way. A recreation of the Southampton docks had been built next to the Titanic set in Rosarito, and the intent had been for Legato to film elements there during breaks in the main unit shoot. But there were no breaks. "I didn't get a chance to film anything in Mexico. Jim was shooting the dock scenes- which were very involved and time-consuming- and he just never relinquished the set long enough for me to get in there and get the crowd shots I needed. We were trying to take advantage of the thousand extras they had down there, but they had them for only three or four days, so that opportunity was missed. Steve Quale eventually shot the extras for us, but by then there were fewer of them and the dock set had been dismantled, so all we had was a bunch of people in a parking lot. Essentially the whole shot had to be created in post."

Because of the sweeping camera move, the transitional reveal of the 1912 Titanic was the most complex and difficult of the Southampton shots. "We knew all along that we were going to have to take the dock elements that were there and convert them to 3-D computer graphics," commented Legato, "because there was no way to get the camera move we needed on a live plate- it was just too big. While I was down in Mexico, one of the things I managed to do was grab a shot from our general viewpoint that was helpful in showing what the buildings looked like from that angle. Roto artist Tonia Young was able to extract some people from it, plus a couple of horses and a few wagons, and use them in our shot- but most of it we had to build from scratch. Mike Kanfer, who was down there also, went around and took still photographs of all the structures for our matte painters to reference. Then, back at Digital Domain, the dock set was recreated as a 3-D digital model- since there would be perspective shifts in the shot- and Martha Mack detailed the foreground and midground by using Mike's photographs as texture maps. Charles Darby- who's actually from Southampton, so he was thrilled to do it- painted the background."

Since the Titanic had to be seen completely, and neither the forecastle nor the port-side hull of the Rosarito ship had been constructed, the entire set was replaced with the model ship and surrounded by digital water. Digital smoke and birds and other details sweetened the shot. People on deck- crew members working and passengers walking around or waving to the crowd below- were a subtle blend of greenscreened extras and computer generated characters produced under the direction of animation supervisor Daniel Robichaud and sequence lead Keiji Yamaguchi. Although digital people were also employed to flesh out the milling masses on the dock, most of the thousand or more figures on view were live extras photographed in small clusters, either bluescreen or greenscreen, and then replicated many times over by compositor Jonathan Egstad. "Except for the three hundred extras that Steve Quale shot in Mexico," commented Legato, "all we ever had at any one time was eight to fifteen people. Since these would be 2-D figures going into a shot with 3-D moves, we filmed them from an angle that was somewhere in the middle of the move- not at the beginning and not at the end- in order to minimize the effect of the perspective change. We would shoot our little groups in planes, then shrink them down and place them on digital 'cards' and insert them wherever we wanted in the

3-D environment. With that technique, when the camera move is added, everything offsets and multiplanes properly- and if the moves are small enough, your eye accepts it as a true 3-D event. It's like one step back from computer generated people. You can't have any camera angle you want, but you can have the ones you plan within these general parameters. The real trick to building big crowds out of small clumps of people is making certain that the action is thrown out of sync on all of the cards so that no one will notice that the same people and the same movements are being repeated throughout the frame."

Ground-level views of the entire ship and the bustling dockside were conceptually simpler since they were essentially lockoffs, with just a slight drift imposed to keep them from looking incongruous amidst Cameron's fluid live-action camera work. "Those shots would have been fairly simple if we'd been able to shoot our plates when the dock set was still standing and all the people were there," stated Legato. "But since we couldn't, we had to fabricate everything. The plates shot in Mexico were a start, but the camera angles were sort of a guess. We later found out that to get the ship to look correct in the shot, the perspective on the people was off- so it was tough getting everything to line up. And since the extras were in a parking lot- not next to the ship- some of them were looking in the wrong directions. We fixed that by filming a few extras at Playa and laying them over the foreground so that they blocked the people who were looking the wrong way. So, for a multitude of reasons, those shots that we thought would be fairly straightforward were anything but- and they were hugely important shots that really had to pay off."

Among the last to board the ship are Jack Dawson, a young bohemian artist, and his friend Fabrizio De Rossi, who have, only minutes before, won a pair of third class tickets in a public house poker game. Moments after their embarkation, gangways are withdrawn and mooring lines dropped, and a flotilla of tugboats tows the massive steamship out into the main waterway. "The tugboats were about two feet long," commented Legato, "roughly the same scale as the Titanic. We made two from the same mold,



As the camera moves slowly past the lovers, lost in their passionate kiss, a dreamlike transition occurs as the narrative shifts from past to present. In an uninterrupted shot, spindly rusticles begin forming on the ship's rails, the fiery sunset fades to the murky hues of the ocean depths, and the gleaming bow transmogrifies into its modern-day counterpart as the lovers dissolve from view. The action concludes with a pullback revealing the wreck as being on a video monitor behind Rose- now an old woman played by actress Gloria Stuart. To achieve a smooth transition, all of the live-action and model elements had to be aligned and tracked, frame by frame, so that corresponding moves and images matched exactly. Digital artists then used advanced morphing tools to let the metamorphosis unfold in a nonuniform manner.



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although each was detailed somewhat differently. Erik photographed them on the motion control stage, with a programmed pitch-and-roll movement based on documentary film footage we had studied. Then, for the unique tugboat-style wake, we built a 'wake-maker' that was roughly the shape of the tug and filmed it in a tank on our main stage at Digital Domain. Since tugboats do not have a prow and are designed for power, they have a very chunky wake- so we had to reproduce that. Then we put CG people on the boats- and added smoke and other things."

The Southampton departure- indeed all of the many scenes in which the Titanic model was a principal player- presented brobdingnagian challenges for the motion control stage crew. "The Titanic was the largest model I had ever photographed," remarked Erik Nash, "and a lot of the shots required that the camera get much closer to it than you normally would expect. So holding depth of field was always a battle, compounded by the fact that the daytime shots- which most of the really close ones were- were shot on 5245 stock rated at 32 ASA, which is very slow. Consequently, some of our passes were painfully long. Lighting the model while the camera was right on top of it was also a problem."

The principal stage components of the daylight shots were a beauty pass photographed against black and a matte pass photographed against a fluorescent orange screen lit with ultra- violet light. "Rob and I got into blacklit orange when we were working on the Star Trek TV show," commented Nash, "and we used it a lot on Apollo 13. From a compositing point of view, it seems to provide a smooth, soft matte edge rather than a crisp, hard line- which is generally a good thing. In terms of practicality on stage, for a given amount of ultraviolet light, the red pigments give back the most visible light. So using a fluorescent orange screen gives us shorter exposure times." In addition to the basic matte pass, supplemental mattes were often needed so that passengers and crew could be composited behind the ship's railings. "Those were done quite simply. We had little strips of orange that we set in right behind the rails and lit with black light. Then we just filmed another pass to create the additional matte." All other mattes, of which there were many, were wrangled by rotoscope supervisor Howie Muzika.

Although the Playa Vista hangar was quite large, it was subdivided into several stage and construction areas. "One of the practical issues we were constantly fighting was that the stage we had for the forty-four-foot Titanic was really smaller than it should have been for a miniature of that size," remarked Nash. "Because the vast majority of the shots were backlit, we needed a lot of space behind the ship when we were shooting the beauty pass, in order to get the key light far enough away. We didn't really have that space. As a result, the key light was always closer than we wanted it to be. Because of that, the part of the ship that was closest to the light was a full stop hotter than the part of the ship that was furthest away; so we were always

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feathering that out, which took a lot of time. Tony Anderson, my gaffer, developed some great tricks for blending multiple key lights to simulate a single, infinitely distant source.”

Adding to the overall complexity was the technique being used to composite the backlit vessel. “When you photograph an object that’s backlit,” explained Nash, “you get a bloom, or a glow, around the hot parts that exceeds the boundary of the object itself. If you use your matte as a printing window for the beauty pass, as you normally would, that glow gets chopped off and the object looks pasted on. To keep that from happening, our compositors used the matte to hold out the background, then printed the beauty pass on top without a matte, which preserved the bloom and made the shots look photoreal. In order for them to do that, however, they needed a beauty pass with a background that was very clean and very black. With our small stage and the backlighting situation, that proved virtually impossible. There would be the stand that was holding the lamp up, plus the flags and cutters that were keeping the light out of the lens and off the floor– and all of that would be right in the shot behind the ship. So the elements we were giving them had all these different levels of black, none of which was really black, and that made their lives much harder. But then there were a lot of matting nightmares on this show. The fine rigging on the ship really drove the compositors nuts. If they tried to adjust the matte to hold the wires, then all of the hard edges of the solid portions of the ship were less than ideal. So basically they had to pinch the rigging out of the matte, then use highlights on the wires from the beauty pass to make the wires self-matting.”



A similar narrative shift from past to present occurs as Rose, adorned only in a diamond pendant, poses nude for her artist lover. Pushing in on her face, the camera records a subtle change– starting with her right eye– that gradually spreads across her features, transforming her youthful countenance into the weathered visage of her much older self. Plate photography of Kate Winslet and Gloria Stuart– filmed in distinctly different light– had to be carefully aligned, and disparate facial features seamlessly merged through a phased morph. Since the actresses’ eyes were unlike in both shape and color, to avoid having one simply dissolve into the other– which would diminish the effect– Cameron had the digital team replace Stuart’s eye with Winslet’s, tracking it through every frame so that the eye remained constant throughout.

Night shots proved simpler, even though they required more passes. “To match what the first unit was shooting in Mexico,” said Nash, “we still had our basic beauty and matte passes, but then there were additional ones that we didn’t need for the day shots. There was a light pass on the portholes and windows, which were lit with internal neon, and one on the incandescent practicals on the various decks, both on the vertical wall surfaces and on the undersides of the overhead decks. Most of the lights were built in and just turned on- except for the ones that lit up the funnels. Those were little flashlight bulbs on articulating mounts that we had to place specifically for that one pass because otherwise they would be visible. Altogether, there were about five passes for the nighttime shots- but they went faster than daylight ones because we were using 5279 stock rated at 320 ASA, which is much faster than the 5245.”

After brief stopovers at Cherbourg, France, and Queenstown, Ireland, for the onloading of additional passengers and cargo, Captain Edward J. Smith directs that the Titanic be put to sea. The camera moves from the bridge to the engine room to the boiler room to the prow as the vessel surges forward in what Jim Cameron chose to call his ‘Ode to the Titanic’- a swelling visual montage designed to convey the power and majesty of the world’s largest and most luxurious ocean liner. Incorporated into the sequence is the only totally computer generated shot in the film- an underwater view of the ship passing overhead as her enormous triple screws churn the water. Although a similar shot of the Titanic kicking up silt as she pulled away from the Southampton dock had been filmed underwater using a model, Cameron felt that a digital approach was needed for the later seagoing shot in order to depict, in a controlled and alterable manner, the cavitation effect produced by the rapidly spinning propellers.



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A similar narrative shift from past to present occurs as Rose, adorned only in a diamond pendant, poses nude for her artist lover. Pushing in on her face, the camera records a subtle change- starting with her right eye- that gradually spreads across her features, transforming her youthful countenance into the weathered visage of her much older self. Plate photography of Kate Winslet and Gloria Stuart- filmed in distinctly different light- had to be carefully aligned, and disparate facial features seamlessly merged through a phased morph. Since the actresses’ eyes were unlike in both shape and color, to avoid having one simply dissolve into the other- which

The shot was assigned to data integration and CG simulation supervisor Matthew Butler, whose academic background in fluid dynamics made him a likely choice for the job. Importing into Prisms the LightWave Titanic built by the NT team, Butler and his crew then animated the propellers, added texture and lighting and Areté water, and worked for months on the cavitation bubbles. “The final effect was actually a compromise between what cavitation really is and what Jim Cameron wanted it to look like,” remarked Butler. “Typically, in any sort of liquid, a certain amount of gas is in solution. When a propeller moves through that liquid, low pressure is created on the leading edge of the blade– which, in turn, allows the gas to come out of solution, causing bubbles. Contrary to what you might expect, these bubbles do not stream off. Instead, they collapse almost instantly and disappear. Jim wanted them to stream back a bit, though, because that was the only way to create a visual cue for the speed and movement of the ship. So physics had to bow to dramatic license. We started out using particle systems for the bubbles, but later got better results with a special cavitation shader– basically a noise and fractal pattern that had the appearance of thousands of little bubbles.”

Concluding the ‘Ode to the Titanic’ was a grand reveal of the ship coursing the Atlantic that begins in close on Jack and Fabrizio at the bow rail, leaning out and exhilarating in the moment. In a fluid, uninterrupted move, the camera arcs around them, sweeps nimbly across the forecastle deck and the bridge, climbs up and over the boat deck and through the four towering funnels, then finally pulls back for a full view of the entire ship slicing through a glistening sunlit sea as hundreds of passengers stroll her decks.

Had there been a real ship with real people on a real ocean, the shot would have been simple enough to obtain with a helicopter and a gyro-mounted camera rig. But there was not. The near-full-size Titanic set was sitting in an eight-acre tank– impressive, but hardly an ocean– encroached upon from the east by soundstages and support buildings and flanked further on by rolling terrain and beachfront communities up and down the coast. Even if these visual distractions could be erased from view and replaced with water, there was still that ten percent of the ship deemed unnecessary for the live-action shoot and left unbuilt. As there was no other complete version of the ship, the only option was to use the forty-four-foot model.

“For us,” stated Rob Legato, “it was extremely important that this shot be photorealistic, because it was early in the film and we had to establish for the audience that our Titanic was on the ocean and covered with people– even though almost nothing in the shot was real.” What was real– at least at the beginning of the shot– was a small set piece representing the bow of the ship, barely large enough for actors Leonardo DiCaprio and Danny Nucci to stand upon, that was mounted on a rotating platform and photographed against a greenscreen at the Playa Vista hangar. Since the shot begins with Jack and Fabrizio in the foreground and the ship

would diminish the effect– Cameron had the digital team replace Stuart’s eye with Winslet’s, tracking it through every frame so that the eye remained constant throughout. Pushing in on her face, the camera records a subtle change– starting with her right eye– that gradually spreads across her features, transforming her youthful countenance into the weathered visage of her much older self. Plate photography of Kate Winslet and Gloria Stuart– filmed in distinctly different light– had to be carefully aligned, and disparate facial features seamlessly merged through a phased morph. Since the actresses’ eyes were unlike in both shape and color, to avoid having one simply dissolve into the other– which would diminish the effect– Cameron had the digital team replace Stuart’s eye with Winslet’s, tracking it through every frame so that the eye remained constant throughout.

around them, the live-action had to be composited onto the miniature ship and match-moved as the camera sweeps past the pair and along the deck. "It was impossible to do this shot in any conventional way. First we did the move on the ship to make sure we had it exactly the way Jim wanted it. From there we determined that what we needed, essentially, was a circular move around the actors. That would have been horribly difficult in a greenscreen situation, so Erik Nash did the trigonometry and calculated it all out so that the same effect could be achieved by putting the set and the actors on a rotating platform."

"It was Rob who suggested a turntable," observed Nash, "but the nuts and bolts of it he dumped into my lap. It was a brain teaser- a 120-degree sweep around these people, craning up twenty feet- but it turned out not to be as tough as I thought it would be, once I condensed it down to a math problem. The Kuper motion control software we have allowed me to take the original move that we did on the twentieth-scale ship and, from that, define where the center of the turntable would have to be relative to the ship. Then, using what Bill Tondreau calls 'axis math,' I was able to compute the distance from that center of rotation out to the camera on a frame-by-frame basis. That became a new axis, which was the camera moving in and out relative to the center of the turntable. Kuper has other software features that allowed me to determine the rotation of the turntable. So ultimately, what we did was convert an east-west and north-south move into a north-south and turntable move, removing the big east-west component completely."

None of the motion control systems on hand at Digital Domain- most designed for non-real-time applications such as model photography- would suffice for the live-action work. "I knew we were going to need a fast motion control rig," stated Nash. "Who do you know who acts at two frames per second? So very early on, I got together with Scott Salsa- who runs the machine shop at Digital Domain- and the two of us sat down and designed, from the ground up, a real-time motion control rig. I basically just threw out the broad strokes in terms of how big I thought it ought to be, and then imparted some of what I had learned over the



Coursing at full speed on a calm and moonless night, the Titanic strikes an iceberg that appears suddenly out of the darkness. For a shot in which Jack and Rose, embracing on deck, react to both the shuddering impact and the mountain of ice scraping past, Leonardo DiCaprio and Kate Winslet were filmed on the forward well deck of the Rosarito ship set, which was backed with greenscreen material for the scene. Chunks of ice-representing shards dislodged during the exchange- were pushed down chutes and onto the set.



The iceberg- which ruptures the Titanic's hull- was a model carved out of foam and covered with

years building motion control systems at Image G. Scott took it from there, building what, in my opinion, is the best fast motion control rig in town- incredibly steady even when it's screaming down sixty feet of track at top speed. It only has a six-foot arm, though, so for some of our shots that had significant north-south components, we adapted one of our Tiffen motion control rigs to make an elevator base for the turntable so it would go up and down about ten feet. Sometimes, to get even more speed than we could from just the camera alone, we put that base on tracks and moved both it and the camera toward each other."

fiberglass and wax. Effects director of photography Erik Nash programs a motion control move on the model, which was scaled to match the forty-four foot Titanic so that both could be filmed together, thus enabling the iceberg to be illuminated with lighting from the ship.

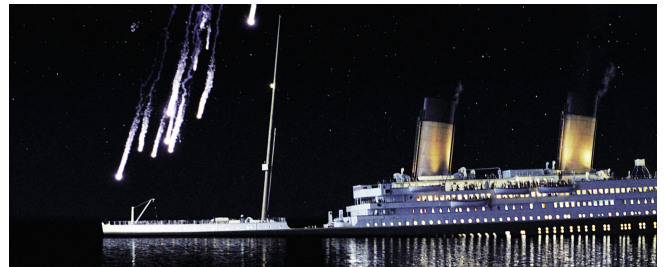
With several components of the desired camera move being created artificially by rotating the set and the actors, further rigging was required to correspondingly move the key lights and air blowers- used to simulate sun and wind- so that they originated from the proper direction, regardless of subject orientation. Another consideration, inherent in all motion control photography, is that it takes a while for the camera rig to get up to speed. "It is, after all, a machine," explained Legato, "and it can't just start and stop at speed- it has to ramp up and then down again. While it's doing that, however, it's eating into the track and into the move; so in a real-time situation with a fast-moving camera, by the time you delete the parts of the move while everything's getting up to speed and back down, what's left in the middle is hardly worth shooting."

A solution was found in a technique that had been devised for shooting sweeping moves on the ship that began or ended in tight closeup. "Sometimes the camera would be just inches away from the model," noted Legato, "and yet we had to maintain full depth of field. One of the ways you do this, of course, is to stop down the lens and increase the exposure time. But with a ship the size of the Titanic, we were looking at twelve-hour passes using this approach. To avoid that, we came up with the idea of altering the shutter speed in mid-shot and ramping the exposure to compensate. Up close, where depth of field is most problematic, we would stop down as far as necessary to hold focus. Exposure times were always long. But as we moved back- usually the largest part of the move- we would up the shutter speed and ramp the exposure to compensate. This would significantly diminish the time required to shoot each pass. I suggested to Erik that we use the same approach on the live-action, and he worked out how to do it. For segments of the shot while the camera was getting up to speed, we would have the actors move in slow-motion. Then, as the shutter speed increased, they could begin to act more normally and we would ramp the iris to insure uniform exposure throughout. Jim was a bit nervous about shooting his actors doing something at six frames per second, but I said: 'Let's just try it. Any parts you hate we can replace with CG.' So we did it, and it worked just fine. Nothing gives it away except for the speed of the clothes blowing in the wind; but unless you're looking for it, you never notice. It's the old magician's sleight-of-hand thing- it's not featured, so you never dream that it's part of the trick." In addition to the sweeping introduction of the ship with Jack and Fabrizio at the bow, several other shots employing roughly the same technique- including one, later on, in which Jack and Rose, falling in love, spread their arms and 'fly' from

the bow- were filmed at Playa Vista during a three-day period after the Christmas break, before the main unit returned to Rosarito.

For Digital Domain, completion of the model photography and the live-action plates for these scene-setting shots was only the beginning. The Titanic still had to be incorporated into an environment of ocean and sky- and peopled with hundreds of digital extras. "For shots like the one of Jack and Fabrizio at the bow," observed Legato, "we could only use the greenscreen footage at the very beginning, because once the camera pulled around Leo and Danny we ran out of track almost instantly. So at that point the live actors become CG characters. The captain and the first officer- who occupy about a third of the frame, top to bottom, as the camera passes over the bridge- are both motion capture figures. And so is everyone else on the ship. Many are just generic- passengers strolling on deck or standing at the rails- but others give specific performances. What I wanted was for the shot to tell a story. Up front we have a crew member mopping the deck. As we pass over first class, we see people walking about or standing- rather stiff and formal- without a lot of interaction. As we continue on over third class, things loosen up and become more animated. We see children running around playing and a couple of guys scuffling near the railing. My idea was that by the end of the shot, the audience will have been introduced not only to the Titanic, but also to the social strata on board. I don't know how many people will pick up on it or appreciate it, but that was the intent."

After months of tweaking and finessing, the social strata of the Titanic was deftly compressed into a library of about forty digital character performances- half of them generic enough to be utilized many times over in the same shot. "It's hard to believe that you could populate a ship using the same people over and over, but in fact you can," insisted Mark Lasoff. "Since the figures were three-dimensional, not two-dimensional, they could be made to walk left to right, right to left, front to back, diagonally- whatever we wanted. In addition, we could offset the timing of the performances so that nothing was being repeated in sync. Camera moves helped, too. Early on, we did a test with a motion capture couple- a man and a woman- and we built a little scene in which we used them twenty-five times. Amazingly, with the timing offset and the camera moving, it was very difficult to tell that they were all the same. So that was a good proof of concept. We found we could get away with a lot. In the film, about eighty percent of the passengers on deck are motion captured- the ones displaying a significant amount of movement. The remaining twenty percent-



Sitting low in the water following her fatal encounter with the iceberg, the Titanic sends up distress rockets in the hopes of summoning aid. The shot- relying wholly on artifice to achieve its photoreal look- blended a multi-pass motion control composite of the ship with digital water and reflections, computer generated people moving about on deck, a practically staged rocket element and digital smoke and stars.



As water swamps the well deck and forecastle, Captain Smith, watching from the bridge, glances up at one of the rockets. The shot featured a foreground greenscreen element of Bernard Hill

people standing and talking, or sitting in lounge chairs- were animated free-hand since there was little movement involved."

on the bridge set, juxtaposed against a sixth-scale miniature of the ship's forward section- one of several large-scale models built by Donald Pennington specifically for real-water scenes of the Titanic foundering and breaking in half.

Once the performances were nicely finessed, Legato- working through character integration supervisor Umesh Shukla- could direct the placement of digital characters and vignettes into any section of the miniature ship, blocking the collective action much the same as a director would on a live-action set. Cameron himself often participated in the process. The most exacting part of the job was making certain that the characters were tacked securely onto the deck- otherwise it would look as if they were floating. As a first step in achieving this goal, a wire-frame replica of the Titanic was constructed in the computer so that the characters could be placed upon it and choreographed with precision in the digital realm.

"To produce our wire-frame of the ship," commented Judith Crow, "we surveyed the forty-four-foot model quite rigorously- with particular emphasis on those parts we thought would be featured the most. This was before they started shooting it, however, so there were instances later on where we had to go in and use photographs and stereo reconstruction techniques to put additional data onto the wire-frame survey data." Once the digital extras were arranged and performing satisfactorily on the wire-frame ship, it was necessary to match-move the wire-frame Titanic to the miniature plate photography so that the characters could be transferred and composited with precision onto the physical model. In most instances, motion control data from the stage cameras served as a starting point. "Having stage data makes match-moving much easier, but it doesn't mean that things are going to line up perfectly- especially when you have multiple-pass shots that are very, very long and take place over several days. Even with the best motion control systems you don't get absolute repeatability. All kinds of things can affect it. In our case, the model was being shot in a hangar located on a marsh- we couldn't even be sure that the ground wasn't settling a bit from pass to pass. So we had to reconcile our data, which we did by tracking occasional frames and measuring the difference between what we perceived in our tracking and what we had in the motion control data- and then make overall adjustments."

Depending on the shot and the elements involved, the level of acceptable deviation varied somewhat. "If all you're adding is sky and ocean, the tolerances are much less demanding than if you're trying to get people to tack onto the deck of a ship," continued Crow. "Even lens aberration comes into play. No lens will give you the sort of pinpoint accuracy that a CG render will. Things will not lock on from the center of frame to the edge of frame. So right from the beginning, we recognized that putting CG people onto the deck of the Titanic was not going to have a 3-D solution entirely. We figured we could get things to within a certain tolerance- say, two pixels at 2K- and then we would probably have to do a bit of 2-D reconciliation on top of that at the very end of the comp. It was time-consuming, and no one was very happy about it; but no one came up with a way around it, either."

Once locked into the plate, the wire-frame characters were enveloped with digital flesh and clothing. "During the motion capture," commented André Bustanoby, "we would have each performer assume an initial pose with arms outstretched and legs apart. We would also

photograph them in that same pose- from all angles and in color- so that we could later use those photos as texture maps.” Cyberscans offered a means by which accurate three-dimensional representations of each performer’s head and facial features could be recorded digitally and incorporated into the computer generated clones. Closeup photographs, later digitized, augmented the low-resolution scan data for particularly close views. In addition to the thirty people selected for motion capture, other individuals were cyberscanned, as well. “I think we did about a hundred head scans in all. Since a lot of the motion capture moves were generic and repeated all over the ship, we were able to replace faces to help disguise that. In most cases, that’s all that was needed. We were also able to change costumes and hats and hair color.”

Alive with digital extras, the Titanic still had to be placed on an ocean of digital water- a task overseen by CG technical supervisor Bill Spitzak and digital ocean supervisor Richard Kidd. “Once we got the look we wanted on the surface of the ocean,” stated Judith Crow, “the hope was always that it be a ‘plug and play’ situation where we would plug in the direction of the sun, the position of the clouds, the speed and direction of the wind, and then just let the system run. It turned out to be not that simple. We really had to learn how to play those parameters to art-direct the water, because often we were cutting in shot-to-shot against real ocean that was beyond the set in Rosarito. For example, there was a scene Jim shot against an extraordinary, almost unreal-looking sunset- one he just happened to get- and we had to match a bunch of shots to that. It was very exacting, and we had to exercise fine control to make the reflections in the water match from one shot to the next.”

The sun was but one of many overlapping reflections in any given shot. “The modified Areté software allowed us to set up ‘cards’- representing objects such as the Titanic- that would then reflect appropriately in the water. It also allowed us to set up ‘sky domes’ which enabled us to specify the gradations we wanted in the sky and the sort of cloud influences we wanted to see reflected in the water. Those were major advances in the software. Prior to that, the coloration of the water was entirely defined by atmospheric conditions. You



For scenes of the Titanic splitting apart and plunging into the sea, the decision was made to use large-scale models in actual water. Since no existing tank facility was found to be suitable, one was designed for the production by Digital Domain special effects coordinator Mark Noel and constructed near the remote desert community of Acton.



In the Pennington workshop, modelmakers assemble the sixth-scale bridge-to-bow section. Also consigned to the shop was a massive eighth-scale midship-to-stern replica- designed to break apart at intervals- plus a quarter-scale funnel for closeup views of the forward stack toppling into the water. While the bow replica required

could define whether the air was dirty or clean and you could have fog density and things like that- which would all have an effect on the color of the water- but it would not suggest the sort of unevenness that is present when you have fluffy white clouds in one shot and looming gray ones in another.”

considerably less detail than the stern, all of the models were fashioned with great attention to accuracy and structural durability.

Once the water had the proper look and reflective quality, it was still necessary to place the Titanic on its undulating surface. “In order to matte in the ship,” stated Crow, “we had to be able to cut an accurate hole in the water that revealed how the waterline would flow against the hull. An unusual thing about the way the Areté people designed their software is that there is no geometry made in rendering their ocean- no polygons or patches or any of the usual 3-D tricks. But we needed to be able to derive that kind of information from their renders so that we could add spray and other interactive effects as the ship plowed through the water. We also needed it so we could incorporate texture maps of wakes and white water coming off the bow and sides of the Titanic, elements which were photographed specifically for this purpose using an actual ship at sea. Areté incorporated the parameters for all of that into their software, as well as a mechanism for producing the actual wake shape that you get off the bow of a ship, which needed to behave appropriately and variably depending on the shape of the hull and how fast the ship was going.”

Assembling the shots was a task equally exacting and time-consuming. “A great many things had to be done before we could even think about rendering water,” asserted Crow. “There was always the challenge of determining, once we had everything on line, how all the pieces melded together and in what order things needed to happen. In some cases, we had 2-D operations that had to happen before we could even begin the 3-D work. If a plate required stabilization or reconciliation, for example, that obviously had to be done before we did any of the tracking. And the tracking obviously needed to be done before we could add water and other 3-D elements. But we also had to do things like create a comp of all the multiple elements of the ship and create a sky dome with appropriate sky and clouds. All of those things had to be in place before we could render the ocean, because the ocean is all about interaction- the color of it basically derives from the sky and other objects that are reflected in it. As for the water itself, there were many separate elements. The textures were one layer. What we termed ‘ocean radiance’- which was the basic ocean surface with the Titanic reflection and sky reflection- was another layer. Surface glitter was yet another. Then there were the wake and white water texture maps- plus the particle system bow spray, which was done with Prisms. All of these elements were rendered individually so the compositors could adjust each if they wanted, for example, to bring the ship reflection out more strongly, for one reason or another.”

Rendering times varied with shot composition. “Shots looking straight down were the quickest to render,” explained Crow, “because the water area was confined and there was relatively little going on. Those we could do in maybe forty minutes per frame. Shots where the horizon was toward the top of the frame took the longest, because we had to render all the way out. There were controls that allowed us to specify how far we wanted to render in full detail- but we found that unless we maintained it almost to the horizon, the ocean would go flat and you could

see it. One of the things we were able to do was take a reduced version of the ship matte and feed it into the system with instructions not to render ocean where the ship would be. If the ship was large in the frame, that would make a big difference. But if it was small and not overlapping the horizon, we could easily have rendering times up around three and a half to four hours per frame.”

Sweetening elements provided by the digital paraphernalia team were essential to maintaining verisimilitude. “We liked to think of ourselves as a digital SWAT team,” stated digital paraphernalia supervisor Kelly Port, “always ready with those little elements no one ever thinks about. Smoke was one of the more obvious ones. For that we went with Dynamation- which is really good in terms of particle systems- because it has a lot of parameters that are very controllable. We would establish wind direction and velocity, factor in the camera move, and position our emitter just below the top of the stack so that the particles would bounce around a bit before going up. And where there was smoke, there were also smoke shadows. For almost everything else we used Prisms- which we like because it’s so open with other packages and with the camera data that comes in. We used that for fish and icebergs and floating debris- plus a lot of other things. We had a number of shots- in the dock sequence and right after the departure- where we added seagulls. Those we did in Softimage by animating just one bird and then replicating it and offsetting it to make it look like there were many more. We also had shots where we needed to replace cables and rigging that did not show up clearly enough in the miniature photography.”

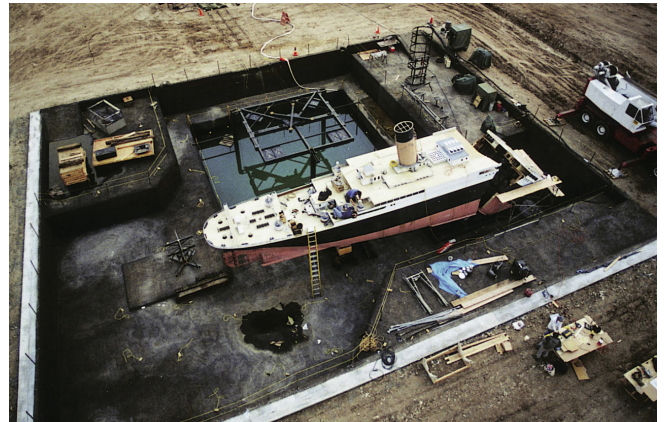
Once the voyage is soundly underway, Titanic settles into its principal narrative as Jack thwarts a suicide attempt by Rose- despondent over the prospect of a loveless marriage- and the two young people from decidedly different sides of the track become friends and then lovers. Aside from a few establishing shots of the ship steaming placidly toward New York, the visual effects in this portion of the film were ancillary to the story and largely invisible. Nonetheless, many shots aboard the Titanic required ocean backgrounds and wakes- or digital extensions to fill in hull sections and other areas of the ship not constructed in Rosarito.

Before ship extensions could be added, proprietary motion tracking software was utilized to determine, with pinpoint accuracy, the three-dimensional components of Cameron’s ever-moving camera. Once that was accomplished, the live-action ship set could be isolated spatially and augmented, as needed, with sections of the digital Titanic. The principal problem in doing this was that the digital ship was an exact replica of the forty-four-foot motion control model, which, in turn, was an accurate reproduction of the actual Titanic. The live-action set, however, was not accurate in that cross sections of the vessel, considered to be unnoticeable, had been removed to reduce its overall length by ten percent. It was therefore compressed, but not in scale.

For Richard Payne, team lead for the digital ship extensions, the task at hand was akin to fitting Cinderella’s glass slipper onto her stepsisters’ feet. “Because the set in Rosarito had a hundred feet or so taken out of it, at random intervals, we had to take the hull that I meticulously built to match the model and somehow squish it and twist it and tweak it to fit. At one point, we considered doing a full remake of our ship based on blueprints of the nine-tenths-scale set; but after calling the art department and looking at blueprints and photographs, we learned that the

crews in Mexico weren't following the prints all that closely. In some places, they were off by feet- nothing that really mattered in terms of the live-action shoot, but if we had built another model to match the blueprints, we would have had two digital models that didn't fit the set. So we decided just to go ahead with the one we had. It ended up working very well, but some of those shots were a heck of a lot tougher than any of us anticipated."

Contributing to the difficulty was the dearth of camera data from the main unit shoot. "Most of the time," recalled Payne, "there was no written-down camera lens information. Sometimes it wasn't evident that a shot would even need extensions until we got the footage from Mexico and looked at it. Fred and I would bring it on-line, and say, 'Okay, we need a little more detail here.' If we were lucky, the DP would remember, 'Oh yeah, we were using a 24mm on this one.' More often, it was a shot in the dark and the 3-D tracking team would have to guess at it. They'd make that guess, give it to us, we'd try to match our hull to it. Eventually, with a lot of huffing and puffing, we'd get the shot to work. Some shots took three months to get the tracking and the fit just right; others took only a week or so." After the 3-D process was finessed to its limitations, a final 2-D tweaking to reconcile all of the elements was performed on a Flame system by team lead compositor David Stern.



As her forward compartments filled with water, the Titanic was drawn down at the bow while her stern rose skyward until the ship split in two at the midsection. For views of the break, the midship-to-stern model was mounted onto a drop mechanism—one of several devices engineered by Mark Noel to progressively sink the enormous models. Next to it, in a deep-water trough, was an elevator rig designed to take the severed stern section of the ship— which upends after the break— to the bottom of the tank.

At several points in the story, the film shifts back to Old Rose and her rapt listeners aboard the Keldysh, always via a stylish transformation effect that imparts a haunting, dreamlike sensibility to the narrative device. The first takes place as Jack and Rose- pressed against the rail at the bow of the ship- share their first passionate kiss against a fiery sunset sky. A subtle change occurs. Rusticles begin to form on the rails and deck, and the background fades to murky blue-black as the lovers dissolve away, the ship's jutting bow replaced by a like view of the rusted underwater wreck. Then the camera pulls back from the video monitor on which the image is displayed and reveals Old Rose in the foreground.

The first step in creating a transformation of this sort entails matching the before and after elements with total exactitude. And since the effect is introduced in phases- often throughout the shot- each frame in the before element must lock precisely with its corresponding frame in the after element. "My particular forte happens to be transitions," explained lead morph artist Christine Lo, "and since a lot of these elements involved live-action and models and such, it was up to me to fudge them whenever something did not line up in terms of perspective or look. Most of the time I used Elastic Reality, which is a morphing tool that allowed me to take anything within the frame and push it and pull it and do whatever I had to do so that the compositors could go from one element to another in a nice clean dissolve. Complicating matters was the fact that anytime I did a morph to match, there was not only the key pass to address, but also the fill pass and any matte passes. Often there were smoke passes, too, which surprisingly were quite tricky, because if you warp the smoke too much, it'll be visible on screen as kind of a weird pulling- like something out of a dream sequence. Scott Rader comped the shot of Jack and Rose kissing on the bow; and with everything perfectly aligned, he was able to bring up the rusticles in phases and have part of the ship begin to look like the underwater Titanic, then bring the rest in later on. It made for a lovely transition."

One of the most striking transitions occurs at the exit of the scene in which Jack nervously sketches Rose in the suite she is sharing with her mother and her fiancé. As the young woman



Crew members prepare to lower the eighth-scale model, suspended from a crane, onto its pivoting drop rig. So large was the replica that much of the ship- including the funnels- had to be transported in pieces and assembled on site.



Don Pennington touches up the paint on the bow. Several weeks were required to ready the models for shooting.

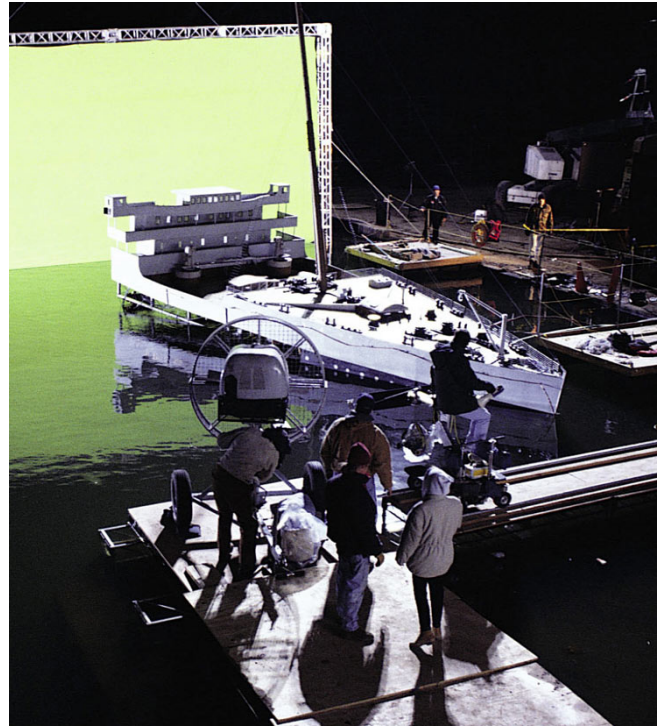
lies nude before him– in an act of awakening love and forthright defiance– the camera pushes in on her eye and hesitates for a moment. Almost imperceptibly at the beginning, wrinkles start to form around the orb and then deepen– and when the camera at last pulls back, eighty-five years have elapsed and Rose is now her much older self.

Provided with plate photography of Kate Winslet and Gloria Stuart, filmed on two separate sets in vastly different lighting, Lo and team lead compositor Claas Henke began by fastidiously aligning the two elements. From there, the task remained to design a phased morph that would convincingly transform Winslet’s young eye into Stuart’s aged one. Not surprisingly, the two were rather unlike– at least up close– being dissimilar in color and shape. Moreover, Stuart’s exhibited the slight cloudiness often evident in older people’s eyes. “Jim Cameron didn’t want one eye kind of fading into the other,” remarked Lo, “so it was his artistic call that we use Kate Winslet’s eye all the way through. In order to do that, we had to take her eye and track it over Gloria Stuart’s. When we put the shot together, however, it looked like we had cheated. Both actresses had held so perfectly still that it looked like two still images going into each other. So after the fact, Claas took one of Kate’s previous blinks and placed it just ahead of the morph– to give it some animation. The other thing we had to contend with was that the effect continues after the camera starts to pull back, so I also had to morph other facial features that were quite dissimilar. By making the eye the center of focus, however, and by offsetting the timing and using a longer transition, I was able to get the nose and the mouth and the rest of the face to move into position in a fairly seamless manner. Even if anyone notices, people’s faces do change as they age– so it’s not unlikely that there would be differences.”

Fiction converges with fact on the fifth night out of port when the Titanic strikes a mammoth iceberg that emerges from the consuming darkness too late to be avoided. Hull plates buckle and rivets pop as vast streams of water spew into the forward cargo hold– one of the first miniature shots completed at the Playa Vista effects annex. An underwater view of the collision was staged in the tank. There an eighth-scale section of the hull, framed with wood and skinned with plates made of lead at the impact point, was fashioned by the model shop and rigged with hydraulic pulls to collapse on cue. “We wanted the iceberg to be bulletproof,” asserted George Stevens, “because we knew it was going to be pounded into the side of the hull again and again. To insure its survival, we carved it out of foam, then covered it with layers of fiberglass. Sections that were to break off when the berg hits the ship were precut and fitted back into place by Mark Noel, who put little slide-away rigs in each so they would all release properly. Cracks were dressed with wax mixed with stearic acid– which lowers the melting point and makes it more brittle– so that when the pieces split off, there would be chips and bits flying away.”

Topside views of the iceberg were also achieved with a miniature. “Shooting the iceberg was very difficult,” explained Rob Legato, “mainly because it was supposed to be just barely visible in the near-total blackness of that night. Even the lookouts failed to spot it until it was too late. So how do you film a dark shape in black water when, from the vantage point you need, it might not even be against the horizon glow or the stars? We tested and tested and tested to come up with some sort of look, and finally wound up shooting the iceberg in multiple passes– key light, fill light, light from the ship– every way we could. That afforded the greatest flexibility during

the compositing phase. About a half dozen shots prior to the iceberg's hitting the ship were eventually farmed out to Mat Beck of Light Matters for compositing. Any where the iceberg is interacting with the ship were done by compositors Darren Poe and Brent Prevatt at Digital Domain."



A greenscreen backing was utilized during filming of the bow's sinking so that the model could later be digitally extended to include portions of the ship beyond the bridge.



The final composite- a view of the bow as water streams over the forecastle and well deck - included greenscreen elements of people on the upper levels. Computer generated lifeboats and water extensions were also employed.

Lighting was easier to justify as the iceberg neared the ship. "The Titanic was very well lit," continued Legato, "so I used the convention that the lights from the ship were actually illuminating the iceberg. That worked fairly well. In fact, with that in mind, we built our iceberg in the scale of the Titanic- which allowed us to shoot both the iceberg model and the ship model together to produce a true interactive light pass. Afterwards we would pull the Titanic away and shoot just the iceberg, since sometimes it was useful to have it that way."



As the ship continues to drop at the bow, the stern rises out of the water, exposing three gargantuan propellers. The shot was realized with the eighth-scale stern section on its mechanical drop rig- which also allowed the model to be tilted. Dwarfed by the ship are dozens of swimmers and a lifeboat, shot greenscreen on an indoor tank stage in Mexico and later composited into the foreground.

Jolted from an embrace by the impact, Jack and Rose look up from the forward well deck to see the mountainous iceberg scraping along the ship, shedding great chunks of ice that skitter across the deck. Live-action for the shot was accomplished in Rosarito against a large greenscreen draped behind the ship set. Emerging from the screen were two chutes- also green- through which stagehands wielding brooms would shove ice on cue. "The hardest part of that shot was all the things we had to fix before we could actually do it," commented Legato. "The backing only went up to a certain point, so everything above it had to be rotoed. Then there was green spill and all the problems that go along with that. Plus the falling ice was not always where we wanted it in the frame. Since the shot was an early one that was needed for the trailer- but Jim had not yet made his cut- I decided to use a tiling technique I had used successfully on other projects. What I did was shoot three different versions of the iceberg at three different pan angles. That way we could piece them together digitally and have a fairly large area of iceberg imagery that, once we got the actual take and derived the pan and tilt information, we could slide against the live-action until the lineup was just right. We also added CG ice to the real ice to make everything fit together better- and we used digital painting to create a scrape on the iceberg as it moved against the ship." One final fixup was not anticipated. "Nobody noticed it for a time, but on the take Jim selected, something strange came out of the chute. After studying it, we realized what it was- one of the guys behind the screen had dropped his broom, and it slid right out with the ice. That was a bit of roto no one expected."

Many survivors of the Titanic remarked on the striking placidity of the ocean that fateful night- a factor which, coupled with there being no moon, contributed to the iceberg's not being sighted until it was too close to avoid collision. Had there been a bit of wind, visual cues from waves hitting the base of the iceberg might well have alerted crew members to the peril in time to take evasive measures. As it was, the blackness was virtually unbroken. Jim Cameron was intent upon re-creating the dead calm conditions. One of the professed advantages of having the big Titanic set in a tank enclosure had been that there would be no wave action to disrupt the desired smoothness of the water. During the Rosarito shoot, however, the production had been bedeviled by winds that tended to blow in soon after sunset each night, fracturing the mirror-glass surface Cameron was attempting to maintain on the eight acres of pseudo-sea that

encircled his massive set. Even a slight breeze could hamper the filming- and these winds were often much more than that. In a curiously sympathetic way, creating and maintaining smoothly surfaced water proved almost as problematic in the digital arena.

"The ocean was supposed to be incredibly calm that night," commented Judith Crow, "which was a problem, perceptually, because a flat sea tends to look unreal to most people. Beyond that, it was a challenge for us because the Areté software did not work terribly well with really low wind speeds. Something about it just couldn't quite match the night reference we had from Rosarito. Ultimately we wound up using a custom ocean shader written in-house by software designer Jim Rothrock to run with RenderMan. Again though, it was hardly plug and play. Since these are night shots- without even a moon- most of the illumination in the scene, and most of our understanding of where everything is spatially, comes from the interaction between the ship and the water and how the reflection lies. So that was a dominant piece in every image. Perfecting it was a process of trying different wind speeds and such, watching and watching, until we got all the elements just right for one particular shot. Then we would go to the next shot- and everything would be different. More often than not, we had to look past what would be physically real and go with what felt right and looked right and cut in right."

Most of the events of the next two and a half hours, as the Titanic foundered and passengers were put into lifeboats, were captured live on set in Mexico- although the digital team provided occasional augmentation in the form of ship extensions. The water team likewise contributed to a number of shots- extending real water with digital water if the scene was wider than the tank allowed, or replacing the real water altogether if gusty winds rendered it too choppy to insure continuity. A few full-ship model shots were also employed to effect- including a dramatic tilt-down from an exploding distress rocket to the stricken Titanic, still ablaze with lights, but terminally low in the water.

Although digital water had been a staple thus far in the film, Rob Legato was of the opinion that climactic scenes of the Titanic breaking in half and sinking should be achieved the old-fashioned way, with large-scale models and real water. "Digital technology gets more and more advanced with each film," observed Legato. "At the start of this one, I pushed for CG water on our sailing shots, not because the technology was altogether there, but because I thought it could be if we pursued it. I was less confident that it would work on scenes where the Titanic had to break apart and sink amidst huge splashes and roiling water. In retrospect, we probably could have done at least some of that digitally- but at the point these decisions were being made, we were already committed to doing CG people and CG water on a scale never attempted before, and I thought: 'We can do this with models. Why not?' Plus doing these kinds of effects physically often results in nice little bits you wouldn't expect- things an animator would never think to add- and I always like to cover the action with several cameras. It just seemed like the right way to go."



Not all of the sinking shots were achieved at Acton. Wide views of the ship- still intact and with its lights yet ablaze- were photographed using the twentieth-scale motion control stage model at the Playa Vista hangar. Digital augmentation, in the form of computer generated ocean, water reflections, passengers- on deck and in the water- and stars, was standard.



The camera racks focus from the sinking liner to a foreground greenscreen element of actor Jonathan Hyde, as White Star Line managing director J. Bruce Ismay, an architect of the disaster who cowardly sought refuge on one of the lifeboats.

After determining that there was not an existing tank facility suitable to their needs, Cari Thomas began searching for a spot in which to build one. Chosen principally for its remoteness and the nighttime absence of city lights in all directions was a private ranch near the desert community of Acton, north of Los Angeles. Engaged to design both the tank and the large-scale mechanical rigs needed for the shoot was independent effects engineer Mark Noel, who had worked for Digital Domain on a couple of recent commercials and had earlier devised the motion base mechanics used to 'fly' the full-size Harrier jump-jet in True Lies. "The tank needed to be big to accommodate the models and the rigging- but not too big," remarked Noel. "We were in the desert, after all, and water was an issue- we had to drill a well to fill the tank. The tank dimensions were eighty by a hundred feet, with the area where we were dropping the ship being eight feet deep and the area we were sinking it being twenty-five feet deep. After we worked out what was needed, we hired a pool contractor to come in and build it using reinforced concrete- a lot of it. With the kind of rigging we were going to have in there, we needed serious concrete. Then we had platforms that we put in- and something like a hundred tie-downs for grip and electric."

Since the Digital Domain model shop had more than enough to do building the twentieth-scale motion control models of the Titanic, the decision was made to hire out for the construction of the three large-scale models that would be needed for the Acton shoot. Principal among them was an eighth-scale midship-to-stern model- sixty feet long- that would be used for shots of the vessel breaking apart and being swallowed by the ocean. There was no need to build the front half of the ship for these scenes since, at this point in the disaster chronology, it was already fully flooded and submerged. A larger quarter-scale funnel model was needed, however, for a scene in which the forward stack crumples and topples into



Cut in half for the Titanic's final scenes afloat - an allowable expedience since the forward half of the ship was by now fully submerged- the beauty model is welded onto a hydraulic tilting device used to obtain up-angles of the stern rising.

the water. And for earlier moments in the unfolding disaster, a sixth-scale bridge-to-bow model- forty feet long- was required for views of the ship's forward section sinking into the sea.

Engaged to produce these models was Donald Pennington, a specialist in large-scale fabrications, who on earlier Cameron projects had built full-scale submersibles for *The Abyss* and a full-size Harrier mockup for *True Lies*. Already on the Titanic payroll by way of the art department- constructing the full-size Mir interior as well as all the lifeboats for the big Titanic set- Pennington nonetheless jumped at the opportunity to contribute to the miniature effort. Work began first on the sixty-foot stern section. "This was my eighth or ninth water show," stated Pennington, "so I'm pretty comfortable building things for water. My biggest problem was that I asked for six months to build the model- and I got three. It was quite a crunch. Basically we built it like a real ship. We took the plans, blew them up for loft lines, cut out bulkhead stations and laid a keel. I believe in bullet-proofing my models, so everything was overkill. The keel was eight inches thick by twelve inches wide, and it was kiln-dried so that nothing would warp or dry crooked as we were building. The hull was cross-laminated quarter-inch plywood that we coated with fiberglass and a marine epoxy, then sanded to give it a nice smooth surface. It would have made a beautiful sailing ship. We had plans obtained from the original Titanic shipbuilders for the plating, and we replicated that exactly using vacuformed plates that, on average, were about six inches by eighteen inches, although some were considerably larger. The Titanic had subplates that covered the entire hull, and then doubling plates on top of those for added strength. So we had to put the larger panels, which had one rivet pattern, on first, and then add a second layer of rivet panels in strips running the length of the ship."

As with most model building, the devil was in the details. "I had forty-eight people working for three months," commented Pennington, "and I would say that half of them did nothing but make deck detail from beginning to end. The deck itself was oak veneer cut into individual planks that we glued and pin-nailed into place according to the ship's original blueprints- very time-consuming. The funnels were rolled aluminum with punched rivet detail. We didn't make the lifeboats- those were already gone- but that was all we didn't do. We built the davits and all the pulleys. We built vents and steam winches, door handles and portholes. We made railings and stanchions out of brass- there must have been three hundred feet of railing on the model- all cut and assembled and soldered. We made hundreds of deck chairs out of cast urethane- none of which are probably even visible since the ship is up in the air at this point and everything loose is piled up against the cabin. But they were there. And everything was very sturdily built."

Although the eighth-scale stern section was the first model begun and the first delivered to Acton, it was not the first to go before the cameras. "The eighth-scale model was so large," explained Pennington, "that we were not able to ship it with all the deck detail in place. In addition to being sixty feet long and twelve feet wide, it was twenty-seven feet tall to the top of the stacks- which was taller than the freeway overpasses en route to Acton- so we had to truck it in pieces and assemble it on location. That took two weeks. While that was being done, we shot the sixth-scale bow section."

While larger in scale- due to the need for closer camera angles and the attendant likelihood that anything less would result in badly scaled water- the bow section was both simpler and smaller in size than the stern section. "The model was forty feet long and about sixteen feet wide," noted Pennington, "and went from the bow to the bridge. Construction-wise, it was the same as the stern section except that everything was bigger. Although there was not as much detail as on the other model, we had to build cranes and steam winches and the bottom section of the mast, up to the crow's nest. There was no need for the entire mast because it wasn't going to be seen in the shots we were doing- most of which were low angles from the front, looking back, although we did have a forward angle from the bridge and a couple of overhead crane shots. Since our mast was only half as tall as it should have been, however, we had to build an X-shaped frame at the top so that all the cables and guy lines used to stabilize the mast would extend up from the deck at the proper angles."

Constructed in only six weeks, the forty-foot miniature was transported to Acton and fitted on a hydraulic motion control rig, fabricated by Mark Noel, that would lower the piece gradually into the water for a succession of sinking shots- several of which would later include digital extensions revealing portions of the ship beyond the bridge. "The point of the bow would go under first," said Pennington, "and then the rest would pivot down at the angle our Titanic experts estimated to be correct. So the water would start at the front and just slowly work its way back, spilling over into the forward well deck and up the face of the bridge. The bridge never went entirely underwater with this particular model- at least not deliberately. On one occasion, there was a computer glitch with the rig, and those big hydraulic motors on it yanked the model underwater about four feet in a second and a half,



In Acton, the eighth-scale model- bolted to its drop rig- stands ready for a night shot in which the ship breaks apart. Engineered to split at a designated point just aft of the third funnel, the model was dressed at the rupture area with thin aluminum hull plates that would twist and tear when the ship was released. Limited break-point interiors were also fashioned.



With Erik Nash occupied at the Playa Vista hangar, Rob Legato served as both visual effects

busting loose the whole top of the deck from all the hydropressure. In the end, though, everything went very well.”

Also filmed while the eighth-scale stern section was being assembled were shots of the Titanic’s forward funnel toppling into the ocean- onto swimmers who would later be added digitally- as the ship, still intact, begins to upend from the weight of the water flooding its forward compartments. “The funnel was built in quarter scale,” recalled Pennington, “ten feet tall, with a steel framework inside that Mark fitted with hydraulics so it could be pulled down under control, crumpling the same way each time. For the outside, we used thin aluminum, which not only wrinkled convincingly, but also took rivet detail really well. After each take, all we had to do was pull the skin off and replace it with a new one.” Two takes were accomplished at Acton. Later, however, when Cameron determined that a slight twist and some additional crumpling were needed, the funnel was reshot at Playa Vista.

With Erik Nash fully occupied at the hangar, Rob Legato had donned an extra hat at Acton, serving as both visual effects supervisor and director of photography for the large-scale model shoot. “I’m a cameraman, anyway, and I love to shoot,” stated Legato, “so I figured if I was going to be out there supervising, I might as well be shooting.” Despite its many pluses, Acton was not a happy place to work- at least in November and December when filming was underway. Freezing nighttime temperatures and frequent high winds caused numerous delays, and won vocal disfavor for the site among members of the crew. “It was an arduous shoot- also a very physical one in terms of the models and the huge mechanical rigs. I had never experienced anything quite like it in terms of scale.”

supervisor and director of photography for the Acton shoot. After the initial break, construction cranes hoisted the model from the tank and reset it on the drop rig. The Pennington crew then spent two days restoring it to its near-original state for a second take. The restoration effort included replacing broken wood surfaces on deck, rebuilding cabin structures, removing and replacing torn metal hull panels and remounting fallen funnels.



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By the time the funnel collapse shots were in the can, Don Pennington and his unit had finished assembling the midship-to-stern model that would represent the Titanic in its final moments, splitting in half and plunging into the depths. Sturdily constructed to withstand the punishment in store for it, the model had inside it a box steel frame, roughly ten feet square, fashioned in sections so that it could be broken apart at several points during the course of the action. At the beginning of the shoot, the 15,000-pound model- mounted on a mechanical rig fashioned by Mark Noel- was positioned at a forty-five-degree angle, its forward end fully submerged and its stern well out of the water.



Following the second take with the patched-together model, additional footage of just the stern splashing down was recorded without redressing the break area. The miniature ship break would later be intercut with live-action elements photographed on a full-scale breakaway set in Mexico.

“The rig was essentially a giant hinge- a simple drop mechanism- big enough and strong enough to support this enormous model cantilevered off at an angle,” related Noel. “I had four or five meetings with Frank Ayre, who works for Don Pennington, and he and I designed the big frame inside the model so that it would fit right over my rig and bolt into place. We shared templates so we could build our rig and his boat in two different shops. In fact, the first time they were together in the same place was out in the desert. It was pretty scary, wondering if everything was going to fit as planned- but it did. To secure the rig to the bottom of the tank, we installed bolts called ‘tappable anchors’ that can be drilled and pounded into concrete. Each anchor is good for 10,000 pounds, and we used thirty of them. All we had to do to activate the mechanism was pull one pin- the ‘Jesus pin,’ which was hydraulically operated just by pulling a lever- and the ship would collapse into the water. The Jesus pin also triggered a computer which set off steam and pyro. About four feet below the surface we put a cradle to keep the ship from sinking all the way to the bottom.”

After the model was installed on the drop rig, Pennington and his crew cut it apart- between the third and fourth funnels where the Titanic broke in two- and removed a two-foot section from the steel framework. The ship remained intact because of the support provided by the rig, but it was no longer able to sustain itself unaided. With the now unstable model thus secured, the Pennington team prepped and dressed the break area. “We weren’t doing closeups at Acton, and at this point the ship’s lights were already out,” said Pennington, “so there wasn’t need for a whole lot of specific break detail. Much of it would be lost anyway. But we did prescore the flooring and the cabins so they would split apart in the proper places; and at the separation point on the hull we installed aluminum panels that would tear and pull off. We also needed to show that this wasn’t just a hollow shell. The Titanic broke apart at one of the engine rooms, so in the middle of our hull we put a large shape- like half of an hour glass- where the engine would be. Then we added interior floors and wires hanging out and tubes- and Mark rigged a few spots to throw out steam.”

Noel also mounted a mechanism inside the model to create a bulge in the hull as the split occurred. "Rob Legato was very concerned that we have a bulge in the ship the instant that it broke," Noel observed. "A lot of this is conjecture, I suppose, but the thinking was that the ship would not just have broken in half. The bottom of the ship would have been pushing up as it was breaking. The example tossed around was that if you take a cardboard tube and bend it, it pushes up from the bottom. The only way we could show that on the ship- because most of it was underwater- was to bulge the hull on the camera side. So we installed a simple hydraulic ram to do that."

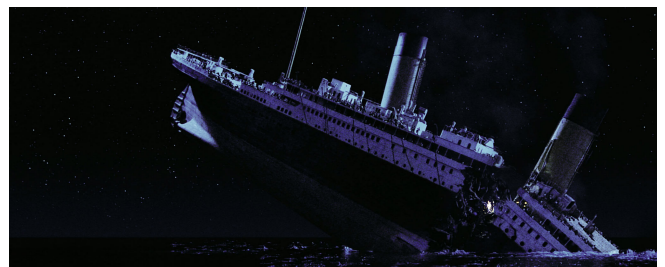
"When the hydraulic pin was pulled," said Pennington, "the model simply dropped- essentially free-fall, but with a slight twist Mark had engineered in. Jim had insisted upon that twist, reasoning that on the real ship, as the metal tore, there would not have been a perfect straight-down break. We agreed. It was all over in a few seconds. The pin was pulled, and the ship broke and fell into the water with a tremendous splash. Afterwards, Mark hooked a construction crane up to the model, pulled it out of the water, reset it on his rig and locked it in place. Then we set to work getting it ready for a second take- which took eight people about sixteen hours to do. We had to replace all the broken wood on the deck, reset the cabin structures, pull all the torn metal off the sides and replace it- quite a lot of work. We also had to remount the second and fourth funnels which were rigged to fall off during the break. We did two hero takes on location, and then several other drops where we just reset the model without redressing it."

Once Legato felt that he had ample coverage of the break, the model was rerigged for subsequent scenes of the severed stern- having risen perpendicular to the water in a sequence of shots achieved later with the motion control stage model- making a final downward plunge into the sea. "For shots of the ship sinking vertically into the water," explained Pennington, "we took the model off the breaking rig and put it on a three-axis elevator rig, also built by Mark Noel, which would lower the model at two feet per second with up to a ten-degree tilt. The model was now about twenty-eight feet long- the rest having split off- and we had to sink it vertically in a tank that was twenty-five feet deep. Actually, it was less than that because Mark's rig was sitting on the bottom taking up a couple of feet. So we did the scene in cuts. After the ship was lowered into the water to about the halfway mark- as far as we could go- we pulled it out, cut off the bottom eleven feet, put the stern section back on the elevator rig, and completed the sinking. We did side shots and rear shots and top shots. Altogether, we sank that model about twenty-five or thirty times."

Though prodigious in scale, it was not the mechanical systems that most preoccupied Rob Legato. "For me, the hardest thing to nail down was the lighting- mainly because, in reality, there was none. The Titanic sank on a moonless night; and by the time it broke apart and went under, all of its internal lights were out. So there was no true source of illumination. Yet we had to be able to see it- and see it clearly. Jim Cameron is a filmmaker who likes real definition in his night shots." Complicating the lighting assignment was the fact that the main unit was still weeks away from shooting the live-action scenes that would intercut with the miniature work. "Without the benefit of seeing Jim's night look, I had to come up with a general way of lighting the ship, anticipating how Russ Carpenter would be lighting the big one. It was supposed to look dark, but we needed a lot of light, not only for depth of field on the model, but also because

we'd be overcranking. Victor Abbene, my gaffer out there, home-built some Musco-type lights- huge twenty-by-forty-foot lightboxes with eight or ten 6K HMIs inside- and we rigged those onto several cherrypickers. The most difficult part was illuminating the model so that the source was kind of nebulous and didn't give itself away. Also, the shape of the ship- which was basically smooth and cylindrical- presented problems because it always picked up a sheen wherever the lights were. We had guys up in the lifts hand-panning each unit to spread the light as evenly as possible." Lighting adjustments that would have been simple on any stage were anything but at the Acton location. "Moving those cherrypickers was quite a job- especially when it rained and they got stuck in the mud. We knew going in that we should have paved around the site - but economy prevailed and we ended up fighting the consequences all the way to the end."

Since the early days of movie making, efforts to film models in water have been plagued with credibility problems because the scale of water is essentially unalterable. Though the disparity in scale between miniatures and water can be disguised to a degree, it is generally considered unwise to have models smaller than quarter-scale in a water environment. In the case of the Titanic, however, a quarter-scale midship-to-stern model would have been too costly to build and too ungainly to work with, so a means had to be devised to break up the syrupy surface and oversize bubbles characteristic of 'miniature' water. Since air had to be expelled from the ruptured Titanic as it slipped into the sea, vigorous churning of the water was considered the most straightforward and plausible way to disrupt the surface and disguise the disparity in scale. "Most of the turbulence was created with air mortars," noted Noel. "We mounted three big ones down at the bottom of the tank- twenty-five feet underwater- and we released them at the start of the shot. It was like a big concussion. The whole tank would shake, and you could feel it. About two seconds later, the air would reach the surface and we would get these big radiating waves of tiny bubbles that looked really good, especially from up high. It was hard coming up with an air mortar that worked under twenty-five feet of water, but anything closer to the surface gave us bubbles that were too big. The lower we went, the more they broke up. In addition to the mortars, we had free air- little hoses with holes in them that we rigged all around the platform so that the bubble effect went down with the ship."

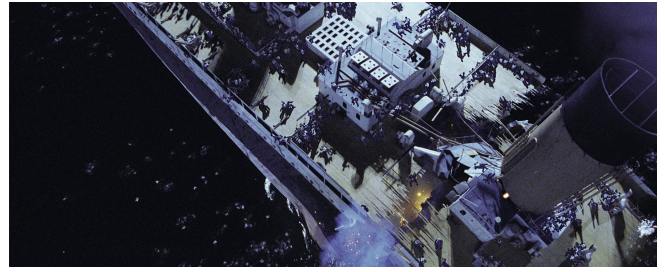


With nothing to support her unnaturally elevated stern, the structurally distressed Titanic begins to split apart.

Although the sequence had been thoroughly storyboarded, Legato covered each segment of the ship's sinking with additional takes and multiple cameras so that Cameron would have a wide range of material from which to assemble his edit. Nearly all of the shots were tight enough that passengers and crew still on board the doomed vessel would need to be seen clinging to handholds and falling into the ocean. Like those on the Titanic, Legato and his team were dangling precariously since there was no safety net in place if the problems attendant to creating digital extras and stunt performers could not be overcome. "At the time," Legato recalled, "Jim was a bit fearful that it might not work. He suggested that we put kicker puppets on the ship and let those carry most of the day. There was also an economic

incentive in that any shot we could get with puppets was one we didn't have to do digitally. Jim's very good at editing bits and pieces of film together to create a sequence out of impressions, really, so I knew he'd be able to cut around and use a second or two of footage here and there before anyone started sensing there were puppets in view. Still, I was reticent about going that route. For one thing, I was shooting well before Jim was, so there was no way I could expect to place puppets so they would interact and correspond with the live-action he would be doing later. Also, we were investing heavily in all of these computer generated people as a means to an end; and we wanted to be able to put thousands of them on the deck, hanging and moving and falling just like the people in Jim's closeups were going to be doing. And finally, the puppets were not exactly an inexpensive option. They would have cost about two grand apiece- and we would have had to wire them all up and make already difficult shots even more difficult by incorporating puppeteering and performance issues. I didn't want those limitations. Jim's a bright guy, and it's never wise to discount anything he has to say, but my feeling was: 'In for a penny, in for a pound. We're gearing up for digital people. Let's just go for it.'" So the 1500 souls on board the Titanic during her final plunge into the sea were nowhere in evidence during the five-week Acton shoot.

All was not yet finished when the Acton unit returned to Los Angeles for Christmas, but the determination was made that what remained could be achieved more expeditiously and with greater control at the Playa Vista hangar. "It was always our intention to shoot the closeups at Playa," asserted Noel, "shots of the deck splitting and the hull tearing apart and scenes with sparks and steam and furniture falling out of cabins. The logistics of doing that at Acton would have been crippling. Even under more favorable conditions, it still took us six weeks to get everything we needed." Because of the time required to refurbish the model and install the mechanical rigging inside the stage tank, the break-apart closeups were put off until late in the shooting schedule- a fortuitous decision, since by this time the corresponding live-action had



As with scenes of tranquil passage earlier in the movie, the inclusion of computer generated people aboard the fracturing liner allowed Cameron to bring his camera in close on miniature action that would formerly have been viewable only from afar. Since the motion capture methodology used to people the film's earlier model shots had been painfully slow and labor-intensive, however, the Digital Domain team devised a more expedient approach for the sinking scenes that combined the best elements of motion capture and free-hand animation.

been shot in Rosarito using hydraulics to pull apart a full-size section of the deck set. With this and the Acton material assembled in a rough cut, it was clearly evident what still needed to be accomplished.

Cut roughly in half to a more manageable length consistent with the closeup framing and the limited size of the stage tank, the eighth-scale Pennington model was detailed- inside and out- by George Stevens and his crew, then mounted on Noel's hinge mechanism. "The original plan was to motion control all of the action," commented Noel, "so I replaced the free-fall pin with computerized hydraulic cylinders. But that turned out to be much too slow, so we ended up going back to the Jesus pin. Because the whole back end of the ship was now removed, we didn't have all that weight pulling down- which we needed to match what was shot in Acton- so I ran a cable up to the ceiling and hung a big 2000-pound weight off it. Everything was controlled by winches. We could lift up the weight, reset the ship to fall, lower the weight onto it, disconnect the winch and pull the pin- and the model would slap down just as it did in Acton. Everything had to happen fast because we were shooting high-speed- usually 96 frames per second- and most of the shots were less than five seconds long."

In addition to side angles of the hull splitting and pulling apart, there were aerial views of the deck doing likewise- into which were incorporated live-action elements filmed in Mexico- and scenes of water streaming into the ever-widening rents. "The Titanic broke right in front of the engine room," explained Noel, "so in our aerial shots, when the ship is coming apart, we had to see all of this water pouring in. Then, when the hull was broken all the way open, we did additional shots by damming the break areas with tempered glass, pumping the water inside down by about three feet- which was difficult because there were leaks everywhere- then popping the glass with squibs so the water outside rushed in. It was greenish and filled with pieces of furniture and other debris- and it scaled perfectly. The effect was great- and in editorial they picked up the shot the instant the glass broke."

During early sequences in the film, members of the CG team had been occupied principally with adding passengers to idyllic shots of the forty-four-foot Titanic model. After the iceberg encounter, their assignment was similar, but more involved and complex. Not only did they have to people that twentieth-scale beauty model, they had to do likewise with the multi-scale Pennington models and, in many instances, even the full-scale set in Rosarito. The mix of replicas presented a formidable challenge for the data integration team. In order to lock the digital characters into miniature and live-action photography of the ship, that photography had to be tracked and a wire-frame replica of the Titanic match-moved in the computer. There were, however, sufficient differences from one model to the next to prevent a single wire-frame replica from representing the ship. So while the twentieth-scale model was thoroughly surveyed prior to its photography, the wire-frame derived from that data could not be used, without modification, for shots involving the other models. Differences were even more acute with the Rosarito set because the sectional slices deleted from the ship to diminish its length by ten percent significantly altered its overall shape.

"We never gave any serious consideration to surveying the set in Mexico," said Judith Crow. "Doing it ahead of time would not have been feasible since we could not predict with any certainty where first unit was going to be filming and what state the set would be in. And during the shoot, there was no point even suggesting that Jim turn the set over to us between shots so our people could go in and take a lot of measurements. We needed another approach- something less obtrusive."

Acting on a suggestion from Rob Legato that stereoscopic imagery might provide a solution, Mike Kanfer designed a rig that consisted of two Nikon still cameras mounted side by side on a horizontal slide bar atop a monopod- which had a stand-alone foot that could be deployed if conditions permitted. "The idea of the 'stereocam' was to have something that could be operated by a single person who could just move around on set and snap pictures unobtrusively without any kind of survey equipment or data recording," explained Kanfer. "By sliding the cameras along the bar and panning them slightly, we could alter the interocular distance and the convergence- although in most instances we used an interocular of thirty-six inches and a convergence of five degrees. After photographing the set simultaneously with both cameras, from as many angles as possible, we would take the resulting image pairs and scan them into our company computer, then run them through a program that calculates three-dimensional geometry based on an interpretation of stereo imagery. The technique worked really well in situations where the stereocam was fifty feet or closer- at twenty-five to thirty feet, we were getting data that was accurate to tenths of an inch. As we got farther away, however, the accuracy tended to fall apart."

For larger sets, or in situations where the stereocam could not get close enough, an alternative approach was conceived. "What we came up with," commented Crow, "was a 'teepee'- a pyramid structure, about a meter high, made of metal bars with struts- that we could place into the set, either before or after a shot, and photograph from two or more angles using a single still camera. From those photos, knowing the precise dimensions of the teepee and the focal length of the lens, we could reconstruct the three-dimensional geometry of the set. Since the teepee is a known piece of geometry, and because there's always a relationship between the points of the set and the points on the teepee, any point you can see in both images you can



As important as the digital figures themselves was the means by which they were affixed to the model. An exactly precise tracking system was employed in conjunction with a digital representation of the ship to lock characters squarely onto model surfaces in the plate photography. Some of the most expansive shots in the sinking sequence featured more than a thousand digital extras and stunt players.



Since the breakaway cross section of the model filmed in Acton was only sparingly dressed, additional footage with further detailing was photographed at the Playa Vista hangar and digitally inserted into the wide shots. Other digital elements included swimmers and pinpoint stars.

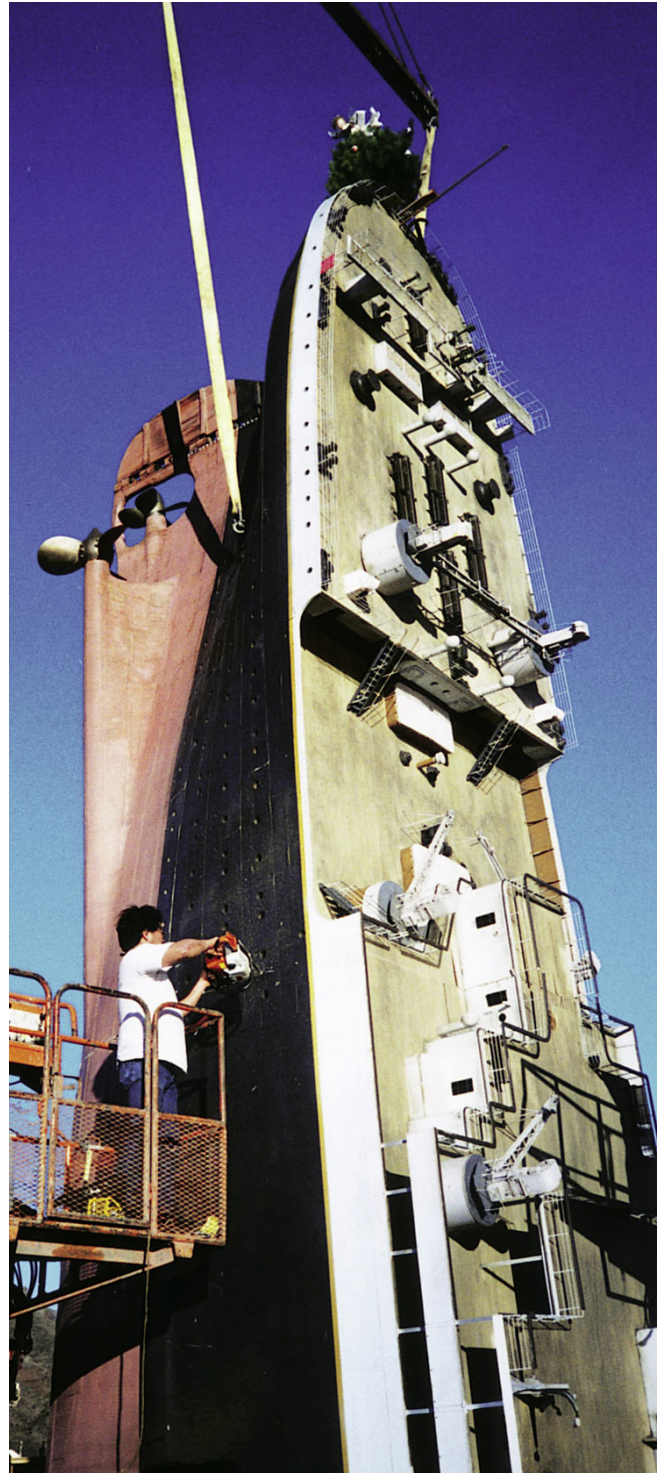
position into view and lock into three-dimensional space. From that we can determine the camera data.”

The results were satisfactory, if not spectacular. “The teepee technique worked quite well for foreground objects, where separation between the two images was distinct,” noted Crow. “On background objects, however, it was not as effective. With the two images only a few pixels apart, it was often difficult to tell if something was thirty feet away, or forty. Still, the approach was a whole lot quicker than surveying every point– and that was the intent. All we had to do was run in, put the teepee down, shoot a couple of quick photographs, grab the teepee and run out. With the data from those photos, we could reconstruct what the set looked like. Then when we got the plate that was shot, we had the data we needed to track the camera move– which was never motion controlled. Usually it was a Steadicam move or big crane move of some sort. We did a lot of that work, especially on the tilting poop deck where we were adding digital stunt people to the shots.” The same technique was used on the Acton models where there was no survey data.

For shots in which digital performers would be called upon to leap or fall hundreds of feet off the upending vessel, standard motion capture was of little value in providing necessary data. Though the technique had served admirably in supplying shipboard tableaux with multitudes of strolling passengers, its capabilities fell short when it came to providing hundreds of digital stunt performers for scenes depicting chaos. “Whenever the action took place in a volume of space that was too big for motion capture,” commented Erik Nash, “we used an alternate technique dubbed ‘roto capture’ where actual film was shot so that animators could study it and duplicate the action. At the beginning of our schedule, we did a big test of this technique out in our parking lot. We brought in a stuntman, dressed him in a bright spandex outfit with colorful Xs and lines all over it, and had him jump eighty feet off a Condor crane into an airbag. The jump was photographed using two Mitchell cameras set at ninety-degrees to each other on scaffolding that was about thirty feet in the air. Both were on motion control pan-and-tilt heads. We used motion control because we wanted to have the stuntman as large in the frame as possible; and to do that manually is kind of a hit-or-miss situation. Since the one thing we know about falling bodies is how fast they fall, we were able to use the Kuper system to plot an imaginary falling object, at a known distance from the camera and at a known height, and then use point tracking to follow the fall. We set up an electric eye on the lift platform, and when the stuntman stepped off and broke the beam, it triggered the cameras to tilt with him. We did several takes and he never went out of frame. It was pretty wild watching these two unmanned cameras follow this falling guy and nail him right into the airbag.”

Once on film, the dual-camera fall footage was scanned into the company computer system for reference and replication by the animation team. “What we were doing was motion capture in a sense,” stated Rob Legato, “except that the capture data was not driving the animation. The animators would have our two live-action views on their computer screens and, frame by frame, they would impart the live moves into a computer mannequin, modifying it from time to time for effect. One of the things about working with stuntmen is that they tend to make the action look bigger than life. We wanted ours to be smaller than life. There were no professional jumpers on the Titanic– the falls needed to be wild and not predictable. We got as much of that as we could

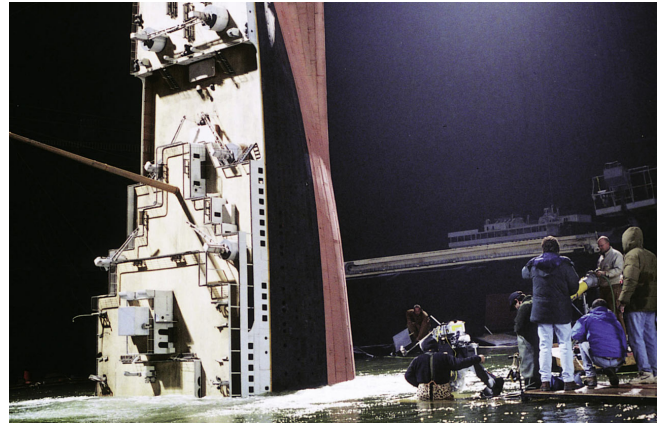
during the shoot, and then the animators took it a bit further with key-framing. They were very good at capturing the nuances.”



Moments after the ship breaks in two, the aft section rises to a full upright position and then plunges rapidly into the sea. For key shots of the upended stern sinking into the water, the rear portion of the eighth-scale model was mounted on an elevator rig over a twenty-five-foot-deep section of the Acton tank.

At one point, the intent was to do more roto capture falls in Mexico- on the sets and from even greater heights into water- but the logistics proved too daunting. Consequently, most of the roto capture took place after the main unit wrapped and Cameron delivered a final cut of the sinking sequence that incorporated fifty more visual effects shots than had originally been planned. A number of the shots involved falls that were to have been done on the hydraulic poop deck in Mexico, but were set aside when several stunt performers attempting them suffered injuries. Rather than risk further bodily harm, Cameron decided to utilize digital stunt performers for the scenes. "We thought roto capture would be the fastest and simplest way to finish these new shots and still keep on schedule," explained Legato. "There was no need for the data to be perfect- it could even be fairly mediocre since it wasn't being used to drive the animation- so we took whatever shortcuts we could." Among the shortcuts taken was the reduction of markers from sixty or more per person to a mere eighteen- just enough to pinpoint the major body junctures. "Even with limited markers to reference, the animators were able to create gross body movement that was very convincing."

On the main stage at Digital Domain, a sparse replica of the poop deck was built and mounted on a hydraulic mechanism that could elevate it to a vertical orientation. "Basically it was a floor and a railing- just enough to mimic the real set," stated André Bustanoby. "There was also a capstan made of rubber so the stunt guys could fall and hit it and roll off." Rather than employ the dual-camera approach to roto capture- which turned out to be quite time-consuming for the animators - a hybrid variant was adopted which blended key-frame animation with traditional motion capture. The full seven-camera system from House of Moves was transported to Digital Domain to capture the poop deck action, which was provided by stunt coordinator Simon Crane and several of his team members. "We had stuntmen falling and sliding, trying to grab on, hitting each other, hanging on ropes- all that sort of thing. It was definitely a full-on, high-energy shoot. When it was over, we had captured more than a hundred individual final moves- about a thousand seconds- which is a lot of data."



Still taller than the tank was deep, the model was lowered to about the halfway point- as far as it would go- then removed and shortened by enough so that what remained could be totally immersed.



On stage at Digital Domain, stunt coordinator Simon Crane and stuntman Joey Box- aided by motion capture animator Michael Sanders- don special suits and markers for a motion capture session on a partial poop deck set mounted on hydraulics. The data thus derived would enable computer animators to supplement live footage of stunt players sliding and falling off the full tilting poop deck, built in Mexico, with similarly choreographed roto capture performances.

“Like the motion capture we did for the deck shots,” noted Mark Lasoff, “the roto capture was used to build a library of performances that we could use over and over again in different shots and in different parts of the frame. Roto capture is really no different than freehand- except that the animators have a frame-by-frame guide along the way. Animator Giancarlo Lari created a digital puppet- driven by inverse kinematics- that had seven control points: one for each limb, two for the body and one for the head. Using a 3-D stick figure derived from the motion capture for reference, the animators would key-frame the IK puppet every ten frames or so- whatever they needed- and that puppet, not the original motion capture data, would drive the animation. This got us away from the inflexibility of traditional motion capture, and also eliminated the need for a lot of the really labor intensive data cleanup. So, in many ways, it was a much faster process- animation time dropped to less than a day per character- and it was considerably less restrictive for the animators. The puppet- which looked like the Tin Man- could be used pretty much as is for long-distance shots where all that was really discernible was the motion. For closeup views, however, we had to skin it with a fully connected body envelope that would bend and turn realistically.”

As the library of digital performances expanded, the methodology used to produce them shifted away from motion capture and roto capture toward a more liberating freehand style of animation. “Some of the shots when the ship is sinking have a thousand people in them,” remarked Lasoff, “all taken from a library of digital characters created specifically for that sequence. About ninety percent of the characters were freehand-animated by some very talented people. The other ten percent were roto captured. Even though we didn’t use it that much, roto capture was very effective for the more complex actions- people climbing over rails and such- which would have been quite difficult to animate from scratch.”

“In the beginning,” elaborated character supervisor Daniel Loeb, “Rob Legato had never worked with character animators before; and I think he felt that he wanted to be able to drive the animation and direct it all himself. Motion capture would allow him to do that, to a degree, so when he pushed for it, we went along willingly- and the results were indeed outstanding. But the process was painfully slow. With all the cleanup and editing involved, it was taking us five weeks per character to do photorealistic work using motion capture data. We had a lot of time, but at that rate it was being eaten up very, very quickly. As Rob became more familiar with the animation process, he started to understand that it was not necessary to rotoscope on every frame and that a lot of the work could be done freehand- or a combination of roto capture and freehand. Soon we were doing characters in only a day or two. Key-frame animation will never equal motion capture in terms of nuance- photorealistic verisimilitude is hard to pull out of a hat- but for the kinds of performances we needed, especially at the end of the movie, our people were able to go that route and still impart an essential human quality. Many of the characters on the sinking ship were totally key-framed- even some that were featured, like the guy who falls and hits the prop and tumbles into the water. Andy Jones did that, and it was all key-frame animation.”



The upended stern- shot motion control at Playa Vista with the twentieth-scale stage model- begins its inexorable descent into the sea. Digital water was made to stream down the hull, and the night sky was illumined with digital stars.



With multiple setups occupying large portions of the hangar's stage space and motion control equipment, a single-axis push-in on the stern, requiring neither pan nor tilt moves, was shot using the Pennington model and a tripod-mounted camera propelled along a straight track.

Shots of the Titanic in her final moments were the most taxing in terms of the number of digital characters. By this time, some two and a half hours after the fatal collision, only the rear section of the ship was still afloat, tilted up at a crazy angle as the tons of seawater flooding her forward compartments pulled the 'unsinkable' vessel inexorably to her doom. All of those still on board and able to make their way astern were congregated on the poop deck in a desperate last-ditch effort to stave off the inevitable. About a thousand people were believed to have ridden the Titanic into the ocean from this tenuous bastion of hope. As the ship continued to pivot at midsection, it broke in two between the third and fourth funnels. The forward section slipped beneath the surface, while the stern fell back onto the water, righting itself momentarily, then tipped straight up and plunged into the depths.

"We had a lot more people in these final shots than we did for any of our daytime deck scenes," commented Lasoff. "There are shots looking down on the Titanic where it's just covered! Unlike the daytime shots, there was no pure motion capture; but using freehand animation and some roto capture we set up a library where we could check out various characters and populate the ship as we saw fit. We used two major setups in building these characters. One was for when the ship was tilted at forty-five degrees and people were sliding and rolling down the deck, knocking into things and each other. That was used for shots up to and including the ones where the ship breaks in half and falls back. Andy Jones was our digital stunt supervisor for those shots. The other setup was for when the Titanic was at ninety degrees and people were hanging from ropes and railings and dropping vertically. These shots were overseen by digital stunt supervisor Mark Brown. Unlike the daytime scenes, where we built a library of digital characters and then populated the deck with them in a somewhat random fashion, animation for the end sequence was built around specific areas of the ship because there was a lot of interaction. Often we would use the same setup from different angles."



Up-angle views of the stern, edging toward a full ninety-degree tilt, were filmed at Playa Vista using the motion control model.

Among the most horrifying moments in the movie is the one in which the Titanic splits in half- a scene absent from earlier cinematic reenactments since conflicting eyewitness accounts had been resolved in favor of those who maintained that the vessel had sunk intact. Only with the discovery of the wreckage some seventy years later- split in two and separated by nearly a third of a mile- was that prevailing view at last disproved.

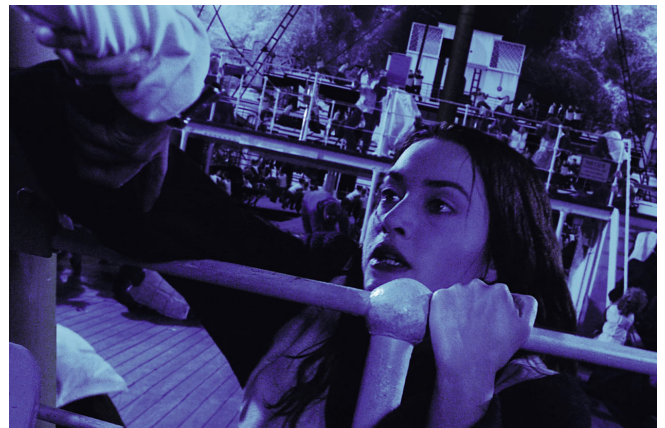
Although the breakup of the ship- the eighth-scale model filmed at Acton- was highly dramatic, it was up to the digital team to impart the human element. "You see a little more than half of the whole ship," said Lasoff, "and at this point everyone has moved to the stern because all of the lifeboats have left and there is nowhere else to go. We put a thousand passengers in that shot- the decks were literally covered with them- so in addition to this glorious ship breaking and the water splashing, you have screaming people scattering, some falling into the chasm, others holding onto rails and lifeboat rigging. Jim Cameron had very specific ideas about what would be going on at this moment in time, and there's a helluva lot of production value in that four-second shot."

In addition to the people swarming on deck, there were many below who had jumped or fallen into the water. Some of those splashing about had been photographed in one of the Rosarito tanks and were simply reduced to ant-size and composited into the miniature shots. Others were computer generated. "Swimming people are pretty easy," remarked Loeb. "You mainly see their arms, and they're just flailing around. Most of them were hand-animated by Gonzalo Garramuno. The hardest things were the falls, where we needed water interaction with our characters. Our animators got very good at finding splashes and really selling the shots that way. To create the impression of people sinking in water, we came up with a shader that calculates the degree of transparency a character would have the deeper it goes. As the character was falling, it would be at one hundred percent; but once it hit the water, it would drop suddenly to fifty percent and then gradually diminish. There were variables, of course- white water is more opaque than black water, for instance- but compositors Chris Roda and Treena Loria were able to set their falloff curves to compensate."

Of the one hundred or so shots in the film peopled with digital characters, about a quarter were contained in the ship's final thrill-ride descent into the icy sea. Not all of the shots, of course, involved digital performers. Many had been obtained live on the hydraulic poop deck rig in Rosarito. But even some of these shots underwent digital sweetening. "Jim got terrific mileage out of the stunt people on this picture," noted Lasoff, "but there were scenes where, for safety or other reasons, he didn't get all the action he wanted during the first unit shoot. So in postproduction, we would go in and add digital fallers and sliders to shots that already had live stunt people. Even we can't tell which are his and which are ours after a while. Another thing we did was add ship extensions to a lot of the shots- medium to long shots on the poop deck where Jim wanted to be back further than the set would allow, but not so far that we could get away with using a model ship and CG characters. Doing ship extensions was a good solution to getting the production value Jim wanted for these shots."

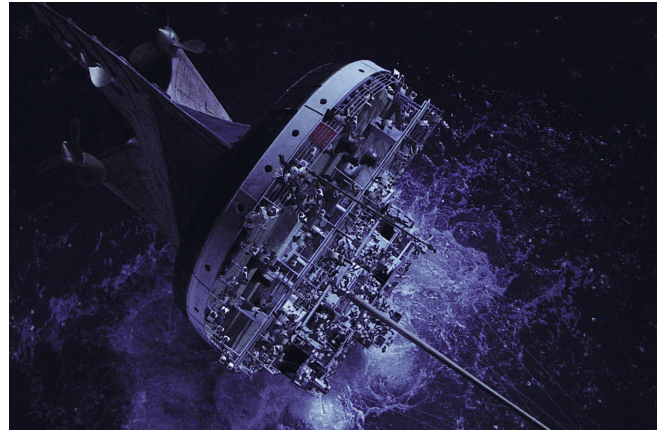
Although most of the eighth-scale Acton footage had scaled exceptionally well- due in large part to the predominant wide-angle nature of the shots and to the aeration of the water- one

critically important series of plates came up short. They were to be used in depicting the Titanic's final moments, looking past Jack and Rose clinging to the outer rail at the stern as churning, frigid water advances upon them, engulfing and sweeping away the last of the doomed passengers below. Only Leonardo DiCaprio and Kate Winslet- filmed on the tilting poop deck set with a greenscreen just beneath them- were live in the scene. All of the other characters were digital stunt players incorporated into miniature photography of water swallowing the ship. Though the intent had been to use plate material shot at Acton, test composites utilizing the footage revealed that the water had scaled unconvincingly. "We knew all along that those were going to be tricky shots," admitted Legato. "The scale of the model was definitely borderline. Originally we wanted a sixth-scale ship, which would have been enormous- as would have been the rig required to support it. Budget-wise, that was not an option. A twelfth-scale model was considered for a while, but that would have eliminated any kind of real closeup work. So we settled on eighth scale- which, with the water turbulence, plus a little foaming agent we added, worked really well for the high-angle shots. The water had a nice upwelling effect. But when you saw it up close, as you did in those final shots, the white water just didn't hold up. You could tell it was basically soap bubbles." The decision was made to reshoot with a larger-scale model.



Having retreated to the stern, Rose is assisted by Jack as she attempts to climb over the aft rail of the poop deck in an effort to ride out the ship's terrifying descent into the ocean. A closeup element of Kate Winslet and Leonardo DiCaprio- atop a small tilting set piece- was filmed on a greenscreen stage at the Rosarito studio. Below them was composited a section of the full-size tilting poop deck crawling with live stunt players and a great many more digital performers.

Don Pennington was called upon once again. "In late April- months after Acton had wrapped- I was contacted about doing a quarter-scale model of the poop deck," recalled Pennington. "Actually it was only about half of the poop deck- from the stern up to just past the docking bridge- but it was still a very big model. We built it using the same techniques as we had on our eighth-scale model, and from the same plans, replicating pretty much everything. It was twenty feet wide and twelve feet deep and, in addition to capstans and benches and railings and all of the other detailing, we laid hundreds of individually cut planks of quarter-inch birch for the deck. Under the docking bridge there were two structures with doors on them that were hinged and rigged with big air mortars so they would fly open when the water overtook them. That was the only mechanical effect on the model."



Wide down-angles on the upended ship featured the Pennington model filmed at Acton. To disguise the disparity between the eighth-scale model and the full-scale water, a foaming agent was added to the water and air mortars were discharged from the bottom of the tank to churn the surface.

Shooting took place on Stage 16 at Twentieth Century Fox where a large thirteen-foot-deep tank had been constructed for the recently completed *Alien Resurrection*. "John Downey- Mark Noel's special effects foreman- built a new elevator rig to sink the model," commented Pennington. "Basically, it was a vertical ramp onto which the model was welded, controlled by a pneumatic winch that would lift the model out of the water and, depending upon how much air was applied, sink it either quickly or slowly." Four sizable air mortars positioned underwater created a churning effect that simulated the expulsion of air from within the sinking ship, while also disrupting the water surface and thus helping to obscure any scaling problems. "The mortars were connected to pipes that had thousands of holes drilled into them. Depending upon the air pressure applied, and the sequencing of the mortars, varying degrees of aeration could be produced. We sank that model 133 times before we got just the right combination of elements."

Hundreds who rode the Titanic into the sea that night would survive the ship's final descent- but only a handful would survive the greater tragedy that followed. Of the sixteen lifeboats drifting nearby- most filled to half capacity or less- only one responded to the desperate cries for help. The others- occupied by people terrified at the thought of being capsized by those struggling in water- remained safely out of reach. All but five who survived the plunge perished in the freezing waters- except in the Jim Cameron version of the event, in which there were six.

Afloat on a piece of wreckage, despondent over the loss of Jack who has succumbed to the cold, Rose nearly allows the returning lifeboat to pass her by. But her recollection of Jack's final urging that she survive and go on with her life- and her promise to do so- stirs her to make her presence known. She is saved. Taking a new name and repudiating her privileged past, she spends the next eighty-five years living life modestly, but exceedingly well, without once sharing her story, even with the children and grandchildren she might never have had, had fate not

intervened. Having returned to the final resting place of the Titanic– and her lost love– she climbs the rail of the Keldysh in the dead of night and surrenders to the sea the priceless diamond she has harbored through a lifetime of need.

She then surrenders herself one last time to the lure of the past. The final scene in the film begins with a graceful passage over a cluster of photographs Rose has arranged on a shelf in her cabin on the ship– images of herself and family that attest to her having indeed fulfilled her pledge to live life to its fullest. The camera pans off the last photo to Rose lying still on her bunk. Then, out of the enveloping darkness, the wreck of the Titanic looms ahead. The camera advances on it, sweeping over the bow and down the promenade deck as shafts of light begin to stream in from the sides. As the move progresses– representing Rose’s spiritual point of view– the promenade reverts to its pristine state and the camera sweeps through a doorway leading onto the grand staircase. Gathered to welcome her are scores of people who had perished on the Titanic– Jack among them. Rose– a young woman once more– steps into the scene, and the two embrace amidst joyous applause as the camera spirals up to the crystal dome above, which dissolves into brilliant whiteness.

The opening of the scene was shot on a small set piece built at the Playa Vista hangar so that the passage over Rose’s photographic life history could be choreographed and recorded via motion control. The remainder of the scene– an uninterrupted shot running nearly two minutes– was a composite of numerous miniature and live-action elements. “The final shot was put together on a Discreet Logic Inferno,” explained night compositing supervisor Carey Villegas, “which is a pretty powerful machine. There were motion control elements that were designed to link together– some with as many as eight or nine matte and smoke passes– but as usual in this type of shot, there was still a fair amount of match-moving and tweaking that needed to be done at the compositing stage. The camera starts out on the Titanic wreck model and comes up to the corridor leading down the promenade deck. At that point there was a cut so that a section of the ceiling could be removed to get the camera inside. Then, since the camera never passed all the way through the entry, we had to do a fake digital zoom through the doorway. As the camera continues on down the corridor and light starts coming in from the side, we morphed to another model of the ship in its new state. We follow that up and around a corner to a doorway– and then inside the doorway we pick up the first unit footage that was shot down in Mexico. Each step of the way required a lot of massaging. The elements had all been shot with every possible lighting condition– so it was up to us to mix and match them until we got something that Jim was happy with. It took months to get everything just right.”

For a director as involved in every aspect of the filmmaking process as Jim Cameron is, visual effects can be frustrating because of the inherent difficulties in tracking progress and providing input over an extended period of time. Few filmmakers would desire or be able to camp out at their chosen effects studios watching the digital equivalent of grass growing.

Since Cameron would be filming in Mexico during much of the visual effects schedule, and sequestered in an editing room for many months thereafter, the production purchased three videoconferencing units from VTEL Corporation so that he could maintain direct audiovisual contact with his production office at Lightstorm and with his effects team at Digital Domain.

The integrated hardware and software system- which sends high-quality audio and video signals over dedicated T-1 phone lines- had its principal hub at Digital Domain. "At each end of the system there are two large monitors with a video camera sitting on top," stated Crystal Dowd. "In the VTEL room we set up at Digital Domain, Jim would be on one monitor and we would be on the other- unless there was another feed. If we were sending him playback or still images- which we could also do- we would see Jim on one monitor and whatever he was looking at on the other. It was a great tool. We could send him film and then look over his shoulder as he studied it frame by frame and talked about the image and pointed to wherever he wanted changes. We also had a Zip drive hooked up so we could take something hot off the press and send it over the phone lines. We would shoot something to one of our PARs- a personal animation recorder- and from that, download it to a Zip and then load that in the VTEL and send it to Jim. It would take a long time- fifteen or twenty minutes- so it wasn't something we did a lot, but the Zips had a lot better resolution than videotape because they were digital. In addition, Jim could load them right into the Avid and cut them into the film."

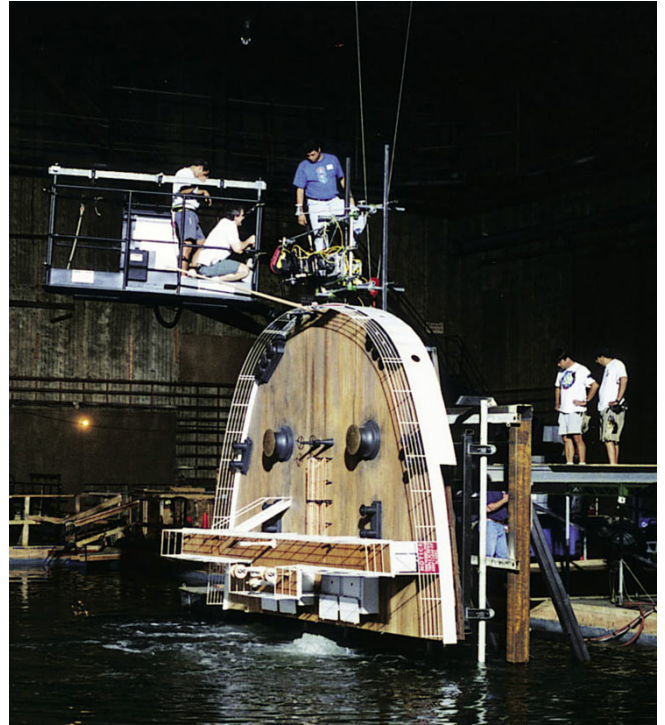
Because of his shooting schedule in Mexico, Cameron rarely had time for more than one VTEL session every day or two while on location. When he returned to Los Angeles and set up a postproduction center at his Malibu home, however, the VTEL went with him and the sessions became much more regular. "We had two sessions a day- seven days a week- and they lasted anywhere from a half hour to two hours," observed Dowd. "Most of the senior supervisors and producers would be there- and we often had guest artists who would come in to talk to Jim directly about their shots. We had a little control unit so we could pan or zoom anywhere around the room as people were speaking. There was no hiding from it. All of the sessions were recorded so that anyone not in attendance could see what Jim had to say about any given shot. Getting that instantaneous feedback really helped move the show along."



Closer views of the doomed ship, with Jack and Rose clinging to the outer rail, employed footage taken on the full-size tilting poop deck in Mexico. A greenscreen placed beneath the vertically oriented set enabled roiling water and digital stunt performers to be incorporated into the action.

Perhaps the single greatest achievement of Titanic, from an effects point of view, was the way in which it shattered the barriers between live-action and visual effects. In his unwavering insistence upon total verisimilitude, Cameron narrowed the gap between the two by treating his sets like models, placing them on hydraulics and sinking them, regardless of size or weight, and by treating his models like sets, putting them in environments that were wholly convincing and populating them with hundreds, sometimes thousands, of people. "I think we intentionally went after the hard stuff," remarked Cameron. "By that I mean the intermediate shot, where you see a lot of the ship- far enough away that it has to be a model, but close enough to see that there are people moving about on deck. Because of the nature of the piece, we had to create the impression that this was a real ship- so Titanic had to be photorealistic to the nth degree. Most effects movies can get away with less. Even a film like True Lies, where we put a great deal of emphasis on photorealism, would not have been seriously diminished if it had been a bit less realistic, because the story itself was inherently a fantasy. Titanic was a historical subject that is very well known. Because of that, there was the necessity to go further, to show it in more minute detail than had ever been seen before. I think the situation you face with a film like this is much the same as you have with really high-end audio where you have to spend twice as much money to get a five or ten percent increase in quality- and there are only a few people in the world who can perceive the difference. So do you do it? My feeling as a filmmaker is that if you can perceive the difference, you have to do it."

Despite the excruciating demands levied upon the effects team by such thinking, most of the artists at Digital Domain embraced Cameron's perfectionist manifesto. "I admire Jim's commitment to this film and his balls-out pursuit of perfection," observed compositing creative consultant Price Pethel, a twenty-year veteran in the digital arena. "I don't believe Titanic could have been done



Although it had been hoped that the eighth-scale tank miniature would produce satisfactory footage for the entire sinking sequence, test composites of shots in which water rushes up the deck toward Jack and Rose showed that the water had scaled poorly in closeup. Hence the decision was made to redo the final plunge with a larger-scale model- a quarter-scale poop deck section constructed by Don Pennington and filmed in a stage tank at Twentieth Century Fox.



As with some fifty other shots throughout the production, digital set extensions, derived from an intricately detailed computer model of the Titanic, were employed to fill in areas of the set- such as the aft hull and propellers- not constructed full-size.

in any other way. People are always asking, 'When are computer actors going to show up in movies?' They'll show up in movies when somebody like Jim Cameron wants them to. When it's important enough and it cannot be done in any other way, that's when it will occur- which is exactly what happened on Titanic. To achieve the imagery that Jim wanted and needed for this film, there was no other alternative than to work on a grand scale and push the boundaries of what can be accomplished with visual effects. In a very real sense, what allowed us to do it at all was the sheer enormity of project- the fact that there were so many extremely difficult shots to do. Each of these shots was so complex that, taken individually, we would probably never have done them. But it was the weight of them all that allowed us to get whatever economies we could out of them. Once you solve the difficulties in one or two shots, you can spread it around among ten or twenty others. So had we not committed to the whole lot, probably none of these wonderful shots would have been in the film."

Still, it was not as though anyone sought out the most difficult and costly solution to given problems. "I love doing a shot cheaply using gaffer's tape or something on a piece of glass," asserted Cameron. "But there was something about Titanic that invariably defied our ability to find easy solutions. Essentially, the problem, from an effects perspective, was not the creating of CG people and CG water- we had very elegant solutions for that- but rather the systems logistics supporting those solutions. When it takes 72 hours to render water for just one shot, you're getting into a level of difficulty greater than anything that's ever been done before, and certainly greater than any of us thought it would be. The same was true with the CG figures - and the throughput of processes like 3-D tracking. There was never a situation where we hit a wall, technologically, and just couldn't go on. Rather, it was the incremental pursuit of excellence that took a toll in time and money. There were thousands, probably hundreds of thousands of man-hours spent on processes that are ultimately sort of invisible, but when done perfectly, create absolute reality. We have one shot, for example, where a rocket goes off over the ship, and drops down and extinguishes in the water. The rocket was shot full-size on the set. The ship is a miniature. All the people going up and down stairs and climbing into lifeboats are computer animated. The water is CG. There are reflections of the model ship and the full-size rocket in the CG water. And the shot is just real! If you were there, that's exactly what it would look like. But those kinds of shots don't just happen. There was an entire philosophy behind getting them just right- and I think a lot of the people at Digital Domain really got into it and took whatever they were doing to that extra level. Rob Legato certainly shares the philosophy of serving no wine before its time- so even before they got to me, I knew that most of the shots had already been sent back five times and reworked. All of that translated into a lot of effort that's not necessarily apparent in the viewing- because in the broad strokes, the shots look pretty much like the cheesy previz video that we did a year earlier. The difference is in the details. But some of the shots are breathtaking in their detail- you can just fall into them. At the end of the day, Titanic is one hundred percent of what we set out to do, if not more- with no compromise whatsoever."

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TITANIC AFTERMATH

ARTICLE BY JODY DUNCAN



James Cameron has often likened the filmmaking process to warfare. The analogy, if obvious, is also apt. The director is the general; limited budgets and schedules, natural elements, human fallibilities and studio politics combine to create the enemy; and the army itself is the cast and crew. Judging by its end credits- a seven-minute scrolling of more than twelve hundred names- Titanic was a very big war.

Many of the artists and technicians listed did not come onto the picture until April 1997, when Cameron was still looking at a possible July 2 opening, and the realization came that Titanic- now with more than three times its original number of effects shots- had outgrown its status as a one-facility show. "There was a huge storage crunch, for one thing," stated Cameron. "Disk space management was a critical issue on this film; and there was a point in mid-post when we realized there just wasn't enough storage at Digital Domain to do the job. We were scrambling around, and they finally said: 'We can't do this movie if we don't buy another terabyte of storage'- which isn't something you hear every day, especially when you consider that a terabyte is probably what the entire Pentagon had ten years ago." Not only was Titanic presenting a storage problem at Digital Domain, it was overloading the facility's available manpower. The obvious solution was to farm out a sizable number of shots to outside vendors. "We decided to bring in other effects companies for the stuff that any competent digital house could do. There was a central body of work that had to remain at Digital Domain; but we took away everything that was increasing the drag coefficient on that central body, and spread it around." What would remain at Digital Domain, and what would be assigned outside the company, was determined in a day-long conference between Cameron, Rob Legato, Mark Lasoff and Mike Kanfer. "We went through every shot at a big round-table meeting- every storyboard- and decided what could be farmed out and what could not. It was a matter of considering every single shot in the film: 'Can this be farmed out?' 'No. Here are the reasons.' 'Can this be farmed out?' 'Yes.' 'Fine. Do it.'" When the process of reassigning shots was completed, Digital Domain found itself with the same number it had originally contracted to deliver, but with a markedly increased workload due to the fact that many of the shots the company assumed were far more ambitious than the ones they had surrendered to other vendors.

With the commissioning of outside companies, the centralized management of the effects project shifted from Digital Domain to the production. An in-house supervisory staff- headed by visual effects producer Camille Cellucci- was hired to coordinate the efforts of all the vendors that would ultimately come on board. Having worked at Industrial Light & Magic on The Abyss and other projects, then later at Sony Pictures Imageworks, Cellucci was a logical choice for point-person in the now multifaceted effects effort. "I got a call from Pam Easley Harris- the associate producer who was handling postproduction supervision- saying that Jim wanted to put someone on the production side to handle the visual effects farm-outs for Titanic," said Cellucci. "They were looking to farm out 350 shots, and it was getting a little crazy." Agreeing to take the assignment, Cellucci set up a base of operations in the production office at Lightstorm Entertainment during the first week in May, and began orchestrating the concurrent efforts at the separate effects facilities, working closely with visual effects wrangler Rob Yamamoto and visual effects editors Bryan Carroll and Steve Moore. "We were talking to a number of effects houses- something that had started before I even came on- trying to work out who could do what. And Jim, having done visual effects movies before, and having worked with many visual effects companies, already had some favorites that he wanted to use."

When the dust settled, the work was divided among seventeen companies. "It was a tremendous effort just to keep tabs on what everyone was doing," affirmed Cellucci. "Rob Yamamoto's assistance was invaluable in that regard. He handled all of the technical elements, getting them out to the various companies, making sure that they worked and guiding the interface with Digital Domain." Communication between Cameron and the various effects houses was conducted via videotaped sessions in which the director gave his input regarding specific shots as they appeared on his monitor. "Bryan Carroll was always with Jim, and he was the mastermind for our end in terms of knowing where all the shots were and having them ready whenever Jim needed to call them up. And Steve Moore- who has a terrific eye, which Jim trusted- often acted as a de facto effects supervisor for the production side. But it was still nuts talking to that many vendors on a daily basis. We had an assistant visual effects coordinator, Robyn Breen, who spent twelve hours a day just taking notes on the shots. We had runners all over the place, running videotapes out to the companies, and we did massive amounts of faxing."

Among the vendors already known to Cameron was Banned From the Ranch Entertainment, whose co-founder, Van Ling, had worked as head of in-house production at Lightstorm before launching his own visual effects company with partner Casey Cannon. BFTR had recently segued from specializing in on-screen computer graphics- for movies such as Congo and Twister- to producing impressive visual effects for Spawn. Ling's history with Cameron led to BFTR's being engaged to composite a computer simulation for the expository scene in which Lewis Bodine- one of the present-day salvage team members- explains to Old Rose the clinical details of the Titanic's sinking. "Since Van had dealt with that kind of thing before," related Cellucci, "Jim thought he would know just what to do. At that point we were only a week away from a preview, so we needed those eighteen shots very quickly. Van managed to turn them

around in two and a half days. They were temp comps, but they looked really good. It was quite a feat.”

Digital Domain had produced the simulation, but it was not completed in time for the main unit shoot- so greenscreen material had been placed on the computer monitor. “Digital Domain sent us the digital file of the entire 2700-frame animation that they had done,” explained Van Ling, “and we composited eighteen cuts of that into the screen area. Some were wide shots, which we burned in and tracked, angling the perspective and getting rid of the green spill. Then there was a medium shot, which was almost a closeup, but you could still see part of the monitor screen around it. It turned out that it had actually been a wider shot that Jim had blown up 400 percent on the Avid to create a closeup. Of course, when you looked at it on film, it was grain city; so we ended up rebuilding it at high-rez from the original footage.” In addition to the sinking simulation, BFTR also digitally processed monitor images supposedly being transmitted from the underwater ROVs. “A lot of that was for closeups during the opening sequence, when the dive crew is exploring the ship remotely, moving through hallways and looking for the safe.”

Impressed with the quality of BFTR’s work, and the fast turn-around times, Cameron and Cellucci assigned the company some additional, more challenging shots. “We began to realize that they could do more than just the video monitor images,” said Cellucci, “and the fact that Van and his team had pulled off that work so quickly and so well gave me the confidence to start giving them other work.” That additional work included composites of computer generated fish produced by Digital Domain for the Mir dive sequence. “There were two closeup shots of fish in the reveal of the Titanic wreck interiors- one in a fireplace and another in a bathtub- but the original fish that Digital Domain had produced weren’t designed for closeups. So Van’s team ended up building the fish and doing the textures and animating it- and it looked terrific. When I saw that they could do not only good composite work, but also photoreal 3-D animation, my whole perspective changed- as did Jim’s. We were happy to give Banned From the Ranch more work, not only because Jim respects Van, but also because it gave us one more option in meeting our deadlines.”

Ultimately, BFTR was charged with compositing the film’s opening image- an extended shot of the Mir submersibles dropping towards and past the camera, then continuing their descent below. Digital Domain had shot the sub models motion control- in smoke to simulate the underwater environment- and those model elements were handed over to BFTR. “Digital Domain gave us about 4900 frames of elements, just for that shot,” stated Ling, “which was 760 frames long. Just the source elements for it took up 70 gig of our storage. We added our own 3-D particles for the particulate matter, which we rendered in ElectricImage on the Macintosh. Then we composited the whole thing- our first 10-bit,



Seventeen companies were brought on during postproduction to handle the burgeoning visual effects workload for Titanic. Using elements supplied by Digital Domain, Banned From the Ranch composited the film’s opening shot of two submersibles dropping toward the ocean floor, and

Cineon-format shot- using a program called Shake. It was a big coup for us.” BFTR was also assigned a shot during the Titanic’s sinking in which Jack, handcuffed to a pipe and abandoned, yells for help as water floods the corridor nearby. “There was no water in the plate- only a mylar blanket laid out halfway down the hall. We added CG water to the back of the hallway, and had the water creep up the hall as well.” In another instance, the company was called upon to digitally extract actor David Warner from a shot of the flooded first-class dining room, since his character had been cut from the scene in editorial. By the end of postproduction, Banned From the Ranch had contributed nearly fifty shots to Titanic.

Like Van Ling, Robert and Dennis Skotak of 4-Ward Productions had history with Jim Cameron, the three having first worked together as effects team members on Roger Corman’s *Battle Beyond the Stars*. In the years since, the Skotaks had contributed to the Cameron films *Aliens*, *The Abyss* and *Terminator 2*- earning Oscars for each in the process. The late-hour call from Lightstorm, asking them to produce shots for *Titanic*, was a welcome one. “Denny and I are both *Titanic* buffs,” related Bob Skotak, “having been interested in it since we were very young. So when Jim asked if we would consider working on the movie, we said: ‘Are you kidding? We’re ready to die for this movie.’”

What Cameron had always valued in the Skotaks was their ability to produce wondrous images through predominantly in-camera means. “Jim describes Bob Skotak as a true artist,” commented Cellucci, “because he has such a great aesthetic eye. The Skotaks can take paper clips and wads of paper and shoot them so you think you’re flying through a solar system. So much of what they do, they do in the classic way- and I love that.”

The classical approach, with a significant digital update, was employed by the Skotaks in seven shots for a sequence in which the *Titanic* is viewed through a pub window in Southampton, as Jack and Fabrizio play poker for a pair of steerage tickets. “The most involved was a fifteen- or twenty-second shot that started on the exterior view,” explained Bob Skotak, “then pulled back through the window and panned around the inside of the pub until Leonardo DiCaprio came in frame.” The Skotaks were provided with a live-action plate- filmed without benefit of motion control- in which a greenscreen had been placed behind the window to allow for the insertion of background imagery. Prominent in the final composition was the *Titanic*. To create that image, Dennis Skotak went to Digital Domain to photograph stills of the forty-four-foot model. “I shot alternate angles to cover everything I could think of,” stated Denny Skotak, “and from

burned a computer animated simulation of the *Titanic*’s sinking onto a monitor screen. Seventeen companies were brought on during postproduction to handle the burgeoning visual effects workload for *Titanic*. Using elements supplied by Digital Domain, Banned From the Ranch composited the film’s opening shot of two submersibles dropping toward the ocean floor, and burned a computer animated simulation of the *Titanic*’s sinking onto a monitor screen.



For fluid-camera views of the *Titanic*, as seen through the window of a Southampton pub, 4-Ward Productions created a dockside tableau featuring a giant photo cutout of the ship surrounded by numerous miniature elements.

several negatives, we tiled together a photographic print that was seventeen feet wide.” Touched up by Rick Rische, the Titanic photo was mounted on a rigid backing and carefully cut out to serve as a giant backdrop for an arrangement of miniatures. “Both the ship and the sky could be 2-D elements,” noted Bob Skotak, “because the ship was far enough away that we wouldn’t see much perspective shifting as the camera pulled back. The important thing, dramatically, was to make the ship dominate the frame– which we did by cheating the size and height of it a bit, relative to the buildings adjacent.” The cutout of the ship was augmented with three-dimensional masts and rigging. “The funnels were cut as separate pieces, angled toward the camera so we would not get a flat effect as we panned along the length of the ship.” A twelve-by-forty-foot sky backing– painted by Rische– was placed eight feet behind the photo cutout.

Strategically positioned around the ship were miniature cranes, cargo crates and sheds, built by 4-Ward modelmaker Jim Towler. “We also bought European-scale trains– the biggest, most detailed ones I could find– and placed them in front of the models,” explained Bob Skotak. “I researched what kinds of trains were actually being used in Southampton at the time; and I modified these models accordingly, painting them and adding additional details.” Because the expensive models strained 4-Wards’ limited budget, they were augmented with cutout versions. “We took still photographs of the trains. Then I scanned the negatives and made digital printouts, varying the photos slightly.” Gravel around the train tracks was simulated with finely ground kitty litter.

In filming the miniature, the 4-Ward team had to replicate the live-action pullback from the window, followed by a pan around the pub. “Unfortunately, there were no measurements of the interior move on the pub,” noted Denny Skotak, “so we had to extrapolate from what appeared to be happening. We would look at what was done in the live-action plate, do our version of it on the miniature, then bipack our model photography with dailies to see how close we were. To shoot it, we used Innovision’s Mini-mover motion control system so we could fine-tune the move and repeat it over and over again. It was a nice little system that let us get close to the ground, set up quickly, then alter the shot quickly when we needed to make an adjustment.”

For people who would be seen walking outside, the Skotaks filmed twenty extras in period wardrobe against a fifty-foot length of greenscreen. Distant people on the deck of the ship were computer generated elements provided by Digital Domain. These and other elements– including steam and smoke– were composited by Mark Loso at Rainmaker Digital under the supervision of Robert Skotak.

4-Ward was also tasked with eight shots depicting the collapse of the ship’s forward funnel during the sinking sequence. Full-size practical shots of the falling funnel had been captured in Rosarito, where a tanker dressed to look like the funnel was lifted by a crane and dropped into the water. Other than two quick cuts thus obtained, however, the funnel’s collapse into the ocean was achieved with a miniature that had been built by Don Pennington, then photographed against greenscreen, both by Digital Domain and, later, the Skotaks.

Given to the Skotaks were plates that included the full-size ship set, people swimming in the water, and even reaction splashes– achieved via primacord explosions– to simulate the effect of

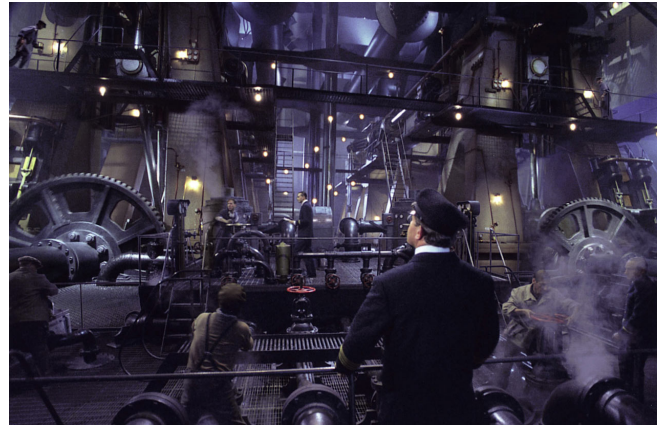
snapped cables striking the water. Missing, however, were the funnel and support cables. On a greenscreen stage, James Cook and Mark Fenlason affixed miniature cables to a bungee rig and manipulated them to create movement that would precisely align with the splashes in the live-action plate. A clip in the camera viewfinder helped determine where on the green floor the cables should hit in order to match up with the live-action splashes. Video playback, checked against the original plate, also served to guide the placement of the miniature cables.

After an initial shot of the cables slapping the water, a high-angle view reveals the funnel toppling to the side. Pennington's 700-pound, quarter-scale funnel model was transported to a stage in Sylmar, where the Skotaks filmed it greenscreen from high atop a catwalk. "We had to match the high-angle perspective that was in the live-action," explained Bob Skotak. "We were up fourteen or fifteen feet, and we had the camera looking down the length of the funnel, with cables extending out from it." Like all of the shots in the sequence, the high-angle view was composited by Alex Ortoll at Title House. "Because it was a digital composite, we knew we'd be able to adjust the timing until it was just right- maybe speed up the cables, remove some frames, define the blur a little bit. We were concerned about being able to read a black cable against dark water- especially if there was a lot of blurring- but we knew we could go in digitally and make the cables look a little more solid, without so much blur, so that we wouldn't completely lose them against the dark water."

Subsequent shots- of the funnel actually fall-ing into the water- were assembled from live elements and greenscreen miniatures photographed by Digital Domain. One of the shots featured a full-size lifeboat, filmed in the greenscreen tank in Mexico. "There was a lot of handheld camera work on these elements," noted Bob Skotak, "and the boat was tossing in the water. When we put it together, it looked like everything was wandering. So we had to figure out how much to correct it." Compositing the foreground lifeboat element with the toppling funnel elements, 4-Ward added enhancements such as steam bursts, sagging cables that were tracked to the funnel, and splash elements as the funnel hit the water. "Digital Domain had done a test shot where they got this surge of water, and Jim fell in love with that- but then they were never able to duplicate it when they shot the actual miniature. So we had to extract that surge from the test, and put it into the final shot of the funnel falling."

Another water-level shot depicts a character thrashing in the foreground. As the camera pans and tilts off of him, the forward funnel twists and falls straight toward camera. "We didn't have a funnel element from Digital Domain that worked for that," commented Bob Skotak, "so we rigged the Pennington funnel model in a little pool of water to give us some reflections at the base. We shot a modified tilt and pan, without actually trying to match the tilt and pan on the live-action. We just wanted the basic dynamic to be there, figuring we could match it much more closely digitally. To get the bending of the metal, we stripped the model and covered it with showcard, which is basically thin cardboard. Painted, it was a dead ringer for the metal funnel." The modified model was positioned in the pool of water at an angle and anchored in place from the ceiling. "Once we pulled the release on the anchor line, the funnel rolled to the side, then fell right on our camera- around which we had built a protective cage."

There was no cage, however, for Dennis Skotak, who was operating the camera, doing a manual pan and tilt toward the falling funnel. “I had a camera assistant behind me, ready to pull me out of the way if there was a problem,” related Denny Skotak. “But, of course, there was only a brief moment to decide whether or not I had to jump out of the way. We shot that funnel drop four or five times to get it just right.”



Scenes within the engine room combined live foreground elements, filmed on a partial set backed by a greenscreen, with a full miniature set photographed and composited at VIFX.

Several of the shots required that 4-Ward add a slight horizon glow and stars– a common assignment for just about every vendor on the show. “It was a very cold and clear night,” noted Cameron, “and survivors remarked on the stars the night before and the night of the sinking. The spectacle of the ship standing like a silhouette against stars is almost universal to all the eyewitness accounts. Plus the stars made the effects shots look much more real– because without them, they’d look as if they were shot against a black curtain. There would be no depth to them at all.”



Engineers tend to the Titanic’s massive power plant– a model peopled with greenscreened crew members.

With so many effects companies contributing starfields and horizon glows, consistency was a major concern. “Digital Domain supplied all of the starfields to those companies,” said Cameron. “We thought that uniformity would be guaranteed by doing that– but that was not the case. What the stars ultimately looked like was determined a lot by how they were dealt with after they were turned over to someone else. Plus the Digital Domain stars were flawed to begin with, because they were done in only two different magnitudes– one very tiny, and the other large. The middle magnitude was missing. I kept complaining to the vendors about the quality of their stars; and it turned out that the problem was inherent in the



Second unit director Steve Quale and effects director of photography Dave Drzewiecki prepare for a motion control shot on a green set erected at

underlying starfield. Digital Domain had figured out how to deal with it, but the other companies had not. I suspect that some of them just said 'screw it' and created their own starfields."

VIFX to align with the catwalks on the engine room miniature.

Among the variables in the starfield shots were brightness and color. "We'd throw a comp together, get it out on film and look at it," related Cameron, "and the stars would either be too bright or not bright enough, or they would be too yellow or too white. Usually they would have to be blued down so that they felt cold, like the rest of the shot. The problem with stars, obviously, is that they are very sensitive to the final timing light of the shot. If you make a four or five point timing correction and darken the shot, the smaller stars will vanish. So it is critical to get the shot timed properly overall. That means you have to cut it into the sequence, and you have to know what the sequence is going to print at- which you may or may not know when you're doing the shot. Fortunately, we reached a point where virtually every shot in the sequence was a digital shot, so we could just keep reprint- ing them until we got them right."

Many of the star shots would be featured near the end of the film, as survivors of the ship's plunge thrash about in the North Atlantic or await rescue in the relatively safe confines of the lifeboats. The coldness of the night would be evidenced by breath vapor that Cameron had determined, during the main unit shoot, would have to be added as a postproduction visual effect- something that had never been attempted before. "It was a pure act of faith," noted Cameron. "We had no tangible test to show that it would work. And we didn't know how much breath we were going to need to sell the concept. If this film had been made two or three years ago, there would have been no breath, because there would have been no way of doing it. The scenes still would have been dramatically strong and compelling, but that extra layer of reality and power would have been missing. I felt that the breath needed to be there if we were going to accurately portray a group of people in 29-degree water and 30-degree air temperature."

Totaling slightly more than one hundred shots, the breath effects represented the largest chunk of work farmed out by the production. While two companies, Pacific Ocean Post and VIFX, were initially charged with doing tests for the effect, the work was ultimately awarded to the latter. "POP's breath looked great," said Camille Cellucci, "but because of the workload they already had, there was a question as to whether or not they could actually do a hundred shots in the available time frame. At this point, we were still looking at a July release, so the speed at which these shots could be turned around was a big factor. VIFX had approached it both digitally and practically at first; but eventually everyone saw that the practical approach would allow them to finish the shots very quickly."

VIFX visual effects supervisor Richard Hollander provided those practical images by shooting real breath generated by a real person in a cold atmosphere. A wood and polyethylene box- the size of a large room- was built on stage and equipped with two air conditioning units that brought the temperature down to between 42 and 48 degrees. Misters inside the box created controllable humidity. The interior was lined with black velvet and lit from above, so that the camera stationed inside could capture an isolated breath image without also photographing the subject. "At first the subject would just breath through a piece of foamcore- covered in black velvet- with a hole in it and a nozzle," explained Hollander. "As we improved the technique, we

exchanged the foamcore piece for a black parabolic mask. The subject, whose lips and teeth were blackened out, would put his head up to the mask and breathe through it.”

Specific conditions had to be maintained for an appropriate vapor to be exhaled and captured on film. “We had a three-degree span that produced the right breath,” observed Hollander. “Anything warmer or colder than that would make the breath disappear. We also had to have just the right level of humidity. Usually, we would start out shooting in heavy humidity, which produced heavier breath, and then we would keep on shooting even as the humidity levels and the density of the breath lessened. For our composites, we wanted to be able to choose from a whole range of breaths, from very dense to very light.”

Of the five days devoted to shooting breath, two were dedicated specifically to shots of the lookouts stationed in the crow’s nest of the Titanic. “The ship was supposed to be traveling at 24 knots,” related Hollander, “so these breaths– unlike the others– had to be moving back quickly from the mouths of those two characters. The others could just billow out any way we wanted, since the night was supposed to be completely still, without any breeze at all. For the crow’s nest shots, we had to build a special structure with a wind machine– a small fan that could be turned to various settings.”

Although the subjects had initially spoken lines of dialogue– producing puffs of vapor that were intended to be tracked to the actors speaking those same lines– Hollander had eventually dispensed with the dialogue. “Invariably, the breath did not show up well enough when the subject was talking. It was a little too subtle. So we ended up not using any of the real lines. Instead, we just had the subject produce a range of puffs– some gentle, some harder– until we had a library of about sixty different breath effects that we could mix and match to the dialogue in the live-action, according to what looked right for each shot.”

The task of selecting the right breath effect for each moment of the live-action fell primarily to CG supervisor Cheryl Budgett. “The most tedious part was having all of this film to choose from,” related Budgett, “and having to go through and say, ‘Okay, I think this breath will work for this shot.’ We tried to group the breath according to shot angles– side views, front views, up or down– so we’d know what group to pick from when we needed a particular angle. But we still had to cut and paste and pick a little from here and a little from there



Stock footage of a dolphin leaping out of the water in front of a ship was digitally treated by Hammerhead Productions and incorporated into a shot of the Titanic getting underway.



For a scene of dolphins cavorting abreast of the ship, Hammerhead enhanced footage of a real

to make certain shots work. In some cases, we had to enlarge them or size them down or rotate them.”

leaping dolphin with two computer generated companions swimming just beneath the surface.

Once a breath effect had been selected for a particular shot, both the picture file and the audio file were transferred to the computer workstation so that the breath could be motion-tracked to the plate photography. Digital Domain starfields were added to many of the shots. Additional tweaking– such as matching color and brightness to the live-action– was accomplished in the final stages of compositing, done on both Discreet Logic Inferno and Silicon Grail Chalice compositing systems.

Also farmed out to VIFX were miniature photography and compositing for shots of the Titanic’s engine room– featured in the ‘Ode to the Titanic’ near the beginning of the film, and in the sequence just prior to the ship’s collision with the iceberg, when the crew makes a valiant attempt to reverse the engines and avoid impact. Live-action for both had been photographed by second unit director Steve Quale– another Lightstorm alumnus– on a set in Rosarito and in the engine room of a real ship. Given carte blanche by Cameron to design the sequence, Quale began by researching the Titanic’s engine room, among the least documented areas of the ship. “There are no photographs of the actual engine room,” remarked Quale, “so we had to rely on original blueprints from both the Titanic and the Olympic, her sister ship. Even with those, there was still uncertainty as to the exact placement of the main controls for the chief engineer, and some of the catwalks– things like that.” To fortify his understanding of the engine room’s layout, Quale researched other ships of the period, as well as more modern vessels. “I went on the Queen Mary and took a look at her engine room, subtracting twenty or thirty years from the technologies.” Quale also went aboard the Jeremiah O’Brien, a decommissioned, but still-functioning World War II Liberty ship berthed in San Francisco Bay. “The Jeremiah O’Brien is one of the last reciprocating engine ships still operable. It has the same triple expansion engines the Titanic did– only much smaller– so I was able to see how all of these physical elements worked and determine how the whole reversing engines sequence should take place.”

After shooting some crude models with a tiny video camera to create an approximation of the sequence, Quale determined that the engine room could be built as a partial set, with greenscreen hung in appropriate areas to allow for the compositing of miniature backgrounds. The set consisted of one twenty-by-thirty-foot section of the engine room, representing an area between the two reciprocating engines. “We built the area that had the main throttle control for the engines on both sides. It also had the reversing engines– the large steam-driven actuators that switch the main engines from forward to reverse. Those would play a pivotal part in the story,” The size of the set was limited by the fact that, late in production as it was, little money remained in the budget for construction. To get maximum usable space for the least expense, the set was made up primarily of flooring, with railings and some valves to create foreground depth. Everything beyond would be a miniature.

To render the shots more dynamic– and avoid tipping off the fact that many of them would be effects composites– Quale chose to film the chaotic impact scene in the engine room with a hand-held camera. “My pet peeve with a lot of greenscreen composite shots,” commented Quale, “is that they lack fluidity in the camera moves. Too often, they are locked off or done

with motion control. For this sequence, I wanted to do something really radical, running around with the camera- realizing that whoever had to deal with compositing the sequence would have a big challenge. I thought if we could pull that off, it would make it look that much more real, because who would think that you'd do an effects shot that way? So I just grabbed an Arri 2C and followed the stunt guys running through the set, with greenscreen in the background."

The engine room miniature that would be put into the greenscreen areas was built by Tony Meininger of Brazil Fabrication & Design, then delivered to VIFX, where it was filmed on a motion control stage by Quale, director of photography Dave Drzewiecki and Hollander. Software developed at Digital Domain enabled the VIFX team to recreate the live-action set in a virtual environment, then precisely track the wild, hand-held camera movement in the live plates. "Using 3-D tracking software," related CG supervisor Edwin Rivera, "our animators figured out exactly how the camera was moving in each of the plates. We then transferred that data over to our motion control computer so that the camera would shoot the miniature background in as much the same way as possible."

To place crew members in areas of the engine room that were strictly miniature, the motion control camera moves on the model were scaled up and used to photograph costumed extras on a minimal set- a multi-level arrangement of catwalks and railings, all covered in green material- that duplicated the spatial relationships on the miniature. "The catwalks were fifteen to twenty feet off the ground," said Rivera, "which was approximately the distance they would have been from the floor of the real engine room." A motion control pass, filmed first without the actors, provided the digital compositors with a means by which to create a difference matte. "With that pass, the computer would know what the set looked like without anyone on it. Then we shot it with people walking on it, again motion control. That made it relatively easy to do a digital extraction. We could pull out the people, their shadows and anything else that affected the clean reference."

Although the motion control elements- both live and miniature- fit together remarkably well, further elements were needed to sell the intended scale of the set. "The model was such a small scale, it was pretty obvious that it was a model in some shots," said Rivera. "With the judicious placing of elements like steam, however, we were able to sell a lot of the miniature that, at first glance, seemed a little too hokey." For the purposes of pulling good, clean mattes, the greenscreen elements had been shot as crisply as possible; but in order to make those elements match the miniature photography- filmed in smoke- they were infused with digital haze in the compositing stage.

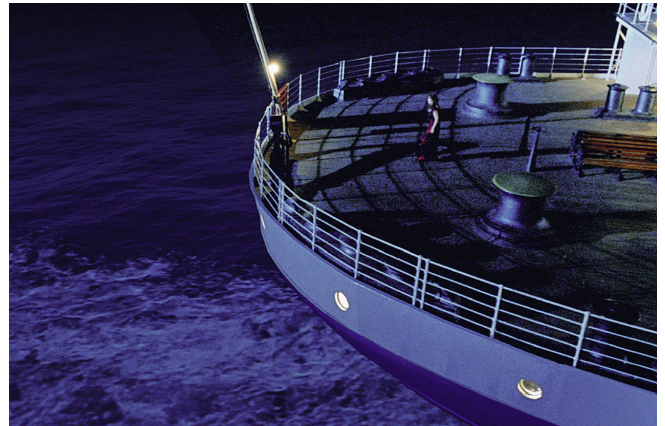
While most of the engine room shots would be achieved through the combination of greenscreen elements, the full-size set footage and model photography, specific closeups were filmed in the engine room of the Jeremiah O'Brien. "I had noticed when I was on the Jeremiah O'Brien how much detail there was on the engines, with all of these big cams and pistons moving," commented Quale. "I didn't think there was any way we could duplicate all of that on a model. So I proposed to Jim that we shoot some of the engine room on that ship. Except for being smaller, its engines were an exact match to the Titanic's." With Cameron's endorsement of the idea, authorization was obtained to film on the ship, and Quale's team went in to refurbish the old steamer's engines and make them look new. The retrofit also entailed

exchanging the ship's fittings with scaled-down versions, in order to make the engines themselves appear larger. "We built one-third-scale industrial lights, and positioned them strategically throughout the reciprocating engines. Then my cinematographer, Roy Unger, did an amazing job of creating a lighting design, based on these practicals, that further enhanced the size of the engines." A modelmaking subcontractor, Vision Crew, was also hired to build third-scale catwalks that were installed on the real ship.

Cramped quarters and 100-degree temperatures made the one-day Jeremiah O'Brien shoot-conducted as a crew of volunteer World War II veterans maneuvered the ship around San Francisco Bay- an arduous one. But the footage achieved- later enhanced with greenscreen engineers filmed and composited at VIFX- was worth the effort.

Besides engine room shots, the 'Ode to the Titanic' featured dolphins racing playfully ahead of the ship, underscoring the celebratory spirit of the passengers on board. Real dolphins swimming and at play had been photographed from a speedboat, and those plates were delivered to Jamie Dixon at Hammerhead Productions for compositing and digital tweaking. While senior visual effects supervisor at Pacific Data Images- before the company closed its Hollywood division and four of its principals went on to form Hammerhead- Dixon had contributed shots to Terminator 2 and True Lies.

One of the supplied plates was a shot looking out towards the horizon, with a lone dolphin jumping in the foreground. "Jim had decided that the single dolphin looked a bit too lonely there all by itself," noted Dixon. "He wanted us to add a couple more swimming underwater nearby." Dixon had originally intended to find appropriate images in the two hours of supplied dolphin footage, scan them in, and composite them into the plate. "The problem was that I couldn't find just the right footage. Nothing really matched the camera angles or the highlights in the water. So we ended up putting computer generated dolphins into the shot- which I had sworn I wouldn't do. I had told Jim I wouldn't take the job if it meant coming up with CG dolphins, because I felt it was impossible- especially in this particular shot, where there would be a live dolphin on the left



Intent upon committing suicide, Rose makes her way to the stern of the Titanic. Footage shot on the poop deck set in Mexico was composited with water plates and other elements by Composite Image Systems.



Twin-screw wakes in the plate photography were altered by CISTo more closely resemble the triple-screw wake produced by the Titanic.

side of the screen and a CG dolphin on the right. But, of course, I did it, because that was the only way to get the shot he wanted.”

Rather than building a dolphin computer model from scratch, the Hammerhead team purchased a generic model from Viewpoint DataLabs. “Viewpoint is a fabulous resource for that kind of thing,” noted Dixon, “but there was still a lot of work to do, since this was a stiff model, without texture or anything. After I painted a color map for the texture, a proprietary system, written by Thad Beier, allowed us to animate the model to kick and flex. Then it was rendered with some glossy highlights.”

The most challenging aspect of the shot was matching the water distortion of the underwater dolphins to that evidenced in the live-action plate. “From looking at all of the dolphin footage,” stated Dixon, “I had noticed that when the dolphins were deeper in the water, they looked like these heavily distorted blue-green shapes; and when they were closer to the surface, the distortion was less severe and the dolphins were a more natural color. So I rendered them with a depth map that allowed me to basically split the dolphins into two segments. I could slightly distort and add highlights to the component of the dolphin that was at a higher elevation in the water; and I could more severely distort and add a different color to that same dolphin when it was deeper in the water. And we just dissolved between those two versions as the dolphin moved up and down.” To put the shot to the ultimate test, Dixon sent it to Cameron on videotape, without revealing that the dolphins were entirely computer generated. When the shot was approved without comment, Dixon knew that the CG dolphins had passed muster.

Another dolphin shot involved taking stock helicopter footage from the film *Under Siege* and modifying it to fit seamlessly into the *Titanic* sequence. “It was an aerial view of a battle cruiser in the ocean,” related Dixon, “with a dolphin making two jumps in front of it. They wanted us to somehow make this plate work for a similar shot in *Titanic*, because it would be less expensive than going out with a big ship and trying to get that specific dolphin footage.” Since the *Under Siege* footage had been shot at a different time of day than the *Titanic* plate, significant color correction was required to match the elements. Another issue was the timing of the dolphin jumps– which Cameron felt was off. “He had us remove sixteen frames from between the two jumps,” said Dixon, “and for some magical reason, that made the pacing of the moment much more aesthetically pleasing to him. So I rotoed out the second dolphin jump and made it happen sixteen frames earlier.” Once the timing was adjusted, Dixon replaced the battleship with a still frame of the *Titanic* miniature, shot by Digital Domain. “We tracked that frame to the battleship in the plate– which was surprisingly easy. One of the things we had to do was cover up a radar dome on the front of the battleship– which we did by sliding a piece of water from the right side of the frame over.” The warship’s bow wake was also manipulated digitally so that it more closely resembled the knife-edged wake of the *Titanic*.

The most difficult of the dolphin shots was a tie-in that showed dolphins and ship together in the same frame. Hammerhead started with two separate elements– the dolphins, and the bow of the *Lane Victory*, a World War II merchant ship, slicing through the water. “The idea was to composite the dolphin footage with the ship and its wake,” stated Dixon, “covering the *Lane Victory* with the *Titanic*. The problem was that the dolphins had been shot from a speedboat, with the camera only ten feet above the water. Jim wanted the *Titanic* to look very big in this

shot. But to look big, we had to be a distance away, which meant the dolphins needed to look about half as big on the screen as they were in the original footage. There was no way to zoom back on that plate, though, because we would have run out of image and seen the speedboat and whatever else was there.” Once again, the only solution was adding computer generated dolphins to the shot. “I was emboldened by the fact that these dolphins were underwater the whole time, so I knew I’d be able to distort them a great deal.”

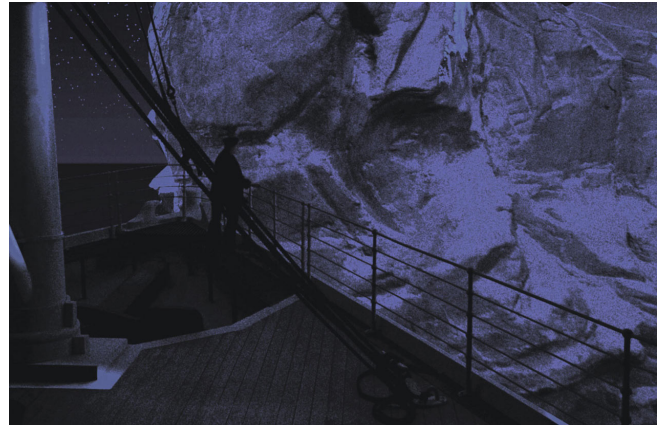
The customized Viewpoint dolphin model was used to produce seven digital dolphins in the shot. "It was important to simulate the group dynamics of dolphins, which are distinctive. They will swim up next to each other, then veer off. They move very quickly. They rise to the surface of the water, and then dive down deep. It took quite a bit of work to get all of that just right- I worked on the animation for three solid weeks."

In addition to the dolphin shots, Hammerhead executed a pull-back transition from a stateroom fireplace in the underwater wreck to that same fireplace as it appeared in 1912. "Jim wanted a very smooth and elegant transition," explained digital artist Rebecca Marie, "rather than a razzle-dazzle morph or something like that. We were given two plates. One was of the full-size fireplace, with Kate Winslet and Leonardo DiCaprio reflected in a mirror above it; the other was a miniature of the sunken fireplace that had been photographed in four passes- in smoke, without smoke, in low light and with a lot of light. We had to intermix those passes on the miniature until we got something that matched the live-action plate. We also had to steady the plates to each other, then reposition them and do a bit of scaling."

While most of the farm-out facilities had come on board Titanic in April or May, Composite Image Systems was recruited much earlier to composite a series of shots in which Rose attempts suicide at the stern of the ship. "We had initially talked about doing that scene practically," remarked Cameron, "with big starfield backings or front projection. But we were only into principal photography for a few weeks when it began to look like that was not going to be feasible, given the fog and wind conditions we were experiencing in Baja. At that point, we realized that we needed more control, so we decided to do it as a greenscreen composite, which added another thirty-five shots to our total."

Having worked closely with the facility on previous projects, Rob Legato felt comfortable turning the sequence over to CIS, where greenscreen photography of Kate Winslet- filmed on the stern of the set in Rosarito- was combined with ocean elements shot at three different angles from the Lane Victory, off Catalina Island. Since the wake from the Lane Victory was not precisely the sort of wake that would have been made by the Titanic, part of the task was to manipulate the imagery through digital means. "The Lane Victory created a double-screw wake," observed CIS visual effects supervisor Ken Jones, "but Cameron wanted a triple-screw wake. So we doubled the water elements, offset their position, and blended them back together to create a third central wake." Catalina was also removed from some shots, while contrast and color manipulation succeeded in making the daytime shots look as if they were filmed at night. "In order to match the look of the reverse angles, a significant color treatment was required for all the foregrounds. In some instances, Kate Winslet's red hair was also isolated and color-corrected. Separate mattes were pulled to preserve her hair edges and the slightly transparent quality of her dress." Starfields were also added to many of the shots.

Additional compositing chores went to Light Matters, which delivered eight shots for the scene leading up to the Titanic's impact with the iceberg. Although Digital Domain had photographed the iceberg element on stage—retaining later shots in the sequence that had the berg interacting with the ship—Light Matters and visual effects supervisor Mat Beck would assemble the shots that first reveal it. A view from the ship's crow's nest posed the problem of how to present the iceberg in the context of a dark, moonless night. "Jim wanted the audience to understand how it was possible for this thing not to have been seen from the crow's nest right away," remarked Beck, "so we had to make the iceberg appear— but without it appearing to appear. To do that, Jim suggested we line up a CG shadow at the horizon, and we ran with that idea. Edson Williams overlaid the stage elements with a shadow that just happened to match the horizon line— so, at first, your eye doesn't really pick up on this thing. Then, as the iceberg gets bigger, you see more detail, which we revealed by animating the contrast and shadow. Finally, by the time you're about halfway through the shot, you suddenly realize, 'Oh my God, there's something out there.'"



Elements provided by Digital Domain were enhanced and composited by Light Matters in a sequence of shots just prior to the Titanic's collision with an iceberg.



Stunt doubles for Leonardo DiCaprio and Kate Winslet were filmed being overtaken by a wall of water. To place the principal actors in the handheld shot, digital face replacements were provided by Pacific Ocean Post.

Computer generated water, provided by Digital Domain, was also composited into the shots by Light Matters- although, ultimately, those water elements had to be digitally manipulated and enhanced for the variety of views. "We ended up generating CG water highlights and reflections," noted Beck, "as well as CG foam elements, CG spray and a CG bow for shadows. One of the problems was that we didn't have a reflection element of the iceberg in the water. So Colin Strause put the iceberg image on a CG surface and rippled it so that we could put that in the water as a reflection. Then we added a CG foam element that Greg Strause put around the iceberg to tie it into the water- as if water was hitting up against the edge of it. The effect was very subtle, because the water was supposed to be like glass that night; but, subliminally, it helped to tie the elements together."



Stunt doubles for Leonardo DiCaprio and Kate Winslet were filmed being overtaken by a wall of water. To place the principal actors in the hand-held shot, digital face replacements were provided by Pacific Ocean Post.

Remaining shots in the sequence reveal the iceberg from the bow of the ship. "There was one in which we pan with Murdoch as he's running out of the pilot house onto the bridge," recalled Beck. "They gave us a greenscreen element of Murdoch and the rail of the ship, and miniature elements of the ship and the iceberg. The camera was panning like crazy- which tended to make the stars disappear- so Erik Liles ramped up the exposure on the stars to keep that from happening. There was a lot of motion blur on the stars and a lot of blurring on Murdoch in the foreground."

A successive scene, in which the engine room crew tries frantically to avoid impact with the iceberg, incorporated shots of the Titanic's massive screws coming to a halt and then reversing. Cavitation effects- unsuccessfully attempted during an underwater miniature shoot- were done digitally by Pacific Ocean Post. "The production approached us with blank plates of miniature propellers," said POP technical director Barry Robertson, "and they wanted us to add the cavitation and misting- little bubbles moving around the props. They brought in some reference footage from *Crimson Tide*, and said, 'We'd like the cavitation to look like that.' And I said, 'Well, that's good, because Matt Hightower and I worked on those shots at *Dream Quest*.' So we were able to follow the template we had developed back then."

In addition to the *Crimson Tide* reference, the POP team looked at videotape of boat propellers underwater to guide them in computer generating the cavitation effects. "Those were smaller craft, of course," said Robertson, "and Cameron's comment about our first few tests was that the effect looked too small. That was, in fact, what they had not liked about the miniature bubble elements they'd tried to shoot. The bubbles were too big and made the propellers look small. So we went back and spent a lot of time trying to create the look of a very large propeller moving through a large volume of water. These propellers were supposed to be gigantic, something like eighteen feet in diameter."

The first step was to rotoscope the blades. “We imported that into Dynamation,” explained Robertson, “where we generated particles for the bubbles, adding turbulence and noise that gave the effect a heavy, liquid feeling. The bubbles were rendered with opaque reflection maps– and were also heavily motion-blurred. We did another pass for the finer, mist-like elements, which we rendered through an in-house renderer. In our final renders, we ended up with over a hundred thousand particles– because the more bubbles there were, the larger the propellers seemed to be and the more water they seemed to displace as they rotated. Then we composited everything together, using Shake software from Nothing Real.”

POP also replaced the faces of two stunt doubles with those of DiCaprio and Winslet for a post-collision scene in which Jack and Rose, running down a corridor toward camera, are suddenly overtaken by a rush of water. “There was a dump tank spilling thousands of gallons of water into that full-sized hallway,” noted POP visual effects supervisor Adam Howard, “so obviously, they couldn’t put the leads in there. Even the stunt doubles were being slammed into walls. So the gag was to take the real faces of Kate Winslet and Leonardo DiCaprio and track them onto the stunt doubles’ heads– something that has been done previously for fairly fast shots with a lot of motion blur, or for very long distance shots. But this is the first instance I know of where face replacement is right in your face. It did not help that it was a slow-motion shot, done with a hand-held camera, with water splashing into their faces and lights flashing on and off.”

POP was provided with Cameron’s selected take of the action captured with the stunt doubles, as well as multiple takes of Winslet and DiCaprio running down the dry hallway. “We scanned three or four shots each,” explained Howard, “then pulled different pieces of both faces from different shots. Kate’s was the hardest to do because she was full-face to camera throughout the shot. Leonardo was behind her a lot of the time, so his face replacement wasn’t quite as difficult.” The final reconstruction of Winslet’s face was made up of forty to fifty separate pieces of film. “In some cases, we’d use an individual frame from one take and slap it into the middle of another, just because the perspectives matched. The most difficult part of it was that the corridor had been constructed with lights every few feet; so as she ran through it, she was running into shadow and then into light. So there were definite shadow and highlight patterns that had to be re-created.”

Complicating the replacement was the fact that the stunt performer was considerably heavier than Winslet. “Kate has a very cleanly defined jawline and a very thin neck; whereas the stuntwoman had a double chin and a very thick neck. So when we got into the shot, we realized that we not only had to replace the face, we also had to replace the neck and chest.” Face replacement finals required extensive digital painting, executed on an Inferno, to ensure a close match of shadows and highlights. “The Inferno is a powerful system that handled the tracking and motion blur beautifully, so we were able, in tracking the face, to completely replicate the motion blur that was in the stuntwoman’s face. It was also great for rotoscoping, of which there was a lot because of the way Kate’s hair– and the stuntwoman’s– was flying around. We had to roto every single hair and every single drop of water in front of their faces– and in some cases add extra water, just to hide little transitions.” Altogether, Howard would spend nearly two months on the face replacement shot. “This was among the hardest shots I’ve ever done– and I’ve been doing this kind of work for seventeen years.”

POP also worked on a shot of survivors thrash-ing around in the icy waters, extending the scope of the scene by substantially increasing their numbers. “Jennifer German, our digital effects compositor, did the shot extension, which starts on Kate Winslet’s face,” explained Howard. “She is in the water, and Leonardo DiCaprio swims up to her. Then the camera pulls back and up, about forty or fifty feet, to reveal all of these other people in the water. It had been shot in a tank that had a termination point at the back, without a green backing or anything, and there had been only about fifty people thrashing around, as opposed to the hundreds Jim wanted to see in the scene. So Jen had to extend the ocean out to the horizon, extend the sky, and replicate the people.” The additional survivors were lifted from a separate plate that had been filmed locked-off, requiring German to match the pullback. “Not only was it a matter of repeating people in the water, but matching the perspective change that occurred as the camera pulled back and up. It was an extremely complex motion track because there was nothing in the shot to track to and everything was moving.” Later in the sequence, sailors in lifeboats, searching the murky waters with flashlights, illuminate hundreds of dead bodies. Like the pullback, the scene had been filmed in a tank with a limited number of people, requiring another extension of water and sky, as well as the cloning of additional bodies from a separate plate.

Cinesite was approached during the farm-out phase to composite starfields and orchestrate complex wire removals, for a total of sixty shots. “Many of the Cinesite shots involved painting out cables that had been used on the actors or stunt people during falling scenes on the poop deck,” remarked Camille Cellucci. “Some of those removals were very tricky because of the way the deck plank lines and the lines of the wires crossed over each other, creating a ghosting effect. Cinesite had some really difficult work to do.”

For wide shots of people falling from the poop deck, Cinesite digital visual effects producer Aaron Dem and visual effects supervisor Jerry Pooler discovered that a standard paint approach to removing the cables did not suffice. “The boat had a rotation on it,” related Dem, “so we had to use a composite approach, creating clean frames of the deck, over which we could then paint the people back in.” Several of the shots had Rose dangling from the poop deck as the ship starts its vertical plunge into the sea. “We put in a computer generated guy, supplied by Digital Domain, hanging there with her. We also removed the safety cables that were on her, which required extensive roto on the railings.” One shot in the sequence, in which a woman slides down the deck, required not just the removal of cables, but of an entire film crew. “There was a crew and a video monitor in the shot, so we had to go in and create a clean frame in order to remove them, then composite the woman back in. That was a several- week-long paint job.”

Cinesite also took on compositing chores for shots of the Titanic's hull crashing down onto people in the water, using model elements that were filmed in the tank in Acton. "You see the hull slamming down and this huge plume of water rising up," stated Dem. "That required a lot of split-screens-taking the original plate we were given, rotoing out groups of people, then shrinking them and giving them perspective to create a better depth of field. After that, we split in water washing over and wrapping around them, inserting a CG jumper that was provided by Digital Domain. We also added a starfield and some overriding camera moves."

Some eyebrows were raised when twelve shots were farmed out to Industrial Light & Magic, Digital Domain's closest competitor. Among the shots assumed by ILM were four split-screens that would reveal the entire ship, from bow to stern, sinking- shots combining elements of the full-size ship set that were never intended to be used together until Cameron came up with the idea during postproduction. "We had to figure out who could handle these very difficult shots in the limited time we had," explained Cellucci. "Digital Domain could certainly have done it; but their plate was so full, we had to look elsewhere. Jim's attitude was, 'If Digital Domain doesn't have time for them, then it better be ILM.' We needed a really experienced facility."

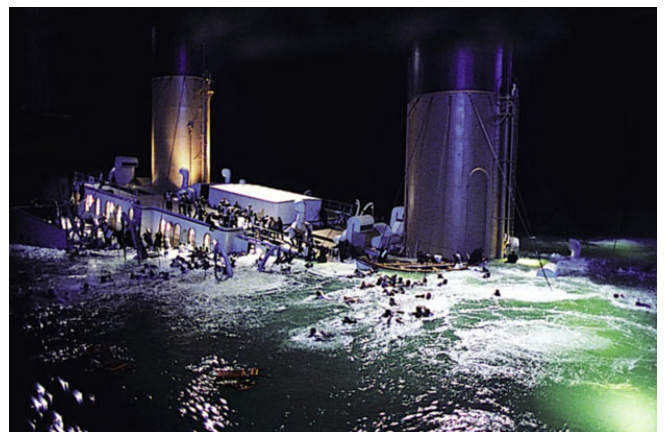
Realizing during the editing process that he did not have a full panning shot of the Titanic as it lay foundering, Cameron had begun playing with pieces of shots on the Avid. "He had a panning shot of the rear end of the full-size ship," commented ILM visual effects supervisor Dave Carson, "and he had another panning shot- taken from a different angle at a different time- of the front end sinking. He put them together on the Avid and asked if we could take the negative and come up with a film- resolution shot that did the same thing. It meant lining up elements that, of



To obtain shots of the full ship set sinking- even though only half of it was rigged to do so- Cameron selected film elements never intended to be used together and tasked Industrial Light & Magic with joining them via complex split- screen compositing.



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course, did not line up at all- but Jim was confident that we could somehow make these two different elements mesh."

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Aligning and blending the two shots, ILM exaggerated the rate of sinking in the final composites by adding water elements from still

other shots to create a new, higher waterline up against the side of the ship. "Once we reached the point where Jim could see that the shots would work," said Carson, "he had us do things like add people running along the lower deck to evade the water. To do that, we rotoed out people running in different sections of the plate and put them into these areas." Stars and a horizon line were also added to each of the shots. "It was very difficult to drop stars into shots that had these large crane and dolly moves. It took a lot of 3-D match-moving. We would take a very low-rez, crude CG model of the Titanic that we built, and line that up with the ship in the plate, which would tell us what the camera was doing and enable us to do our match-moving."

Also on the ILM agenda was a vortex effect that follows the ship's final disappearance beneath the water, seen from the point of view of Jack and Rose, who have clung to the poop deck railing until the last possible moment. "You see the rear of the ship disappear," remarked Carson, "and then the camera follows underwater, where you see Jack and Rose being sucked down into the turbulence as the ship recedes below them." To produce the shot, ILM was supplied with a Titanic model element from Digital Domain- filmed dry-for-wet in smoke- together with underwater greenscreen elements of Winslet, DiCaprio and a few extras. "We took all of those elements and started building up the shot. On the ship, we had a clean pass and a smoke pass, so we were able to balance the smoke over the course of the shot as the ship descends into the depths. The smoke provided the appearance that the ship was receding into obscurity, while CG bubbles- millions of them- were generated to suggest turbulence." After first choreographing the bubbles to rise toward the surface, Carson decided to have them move downward instead. "You always think of bubbles as rising; but when we did that, it just didn't look like the ship and all of these people were being sucked into a vortex. Finally, I realized that if the current was strong enough to pull people downwards, it would certainly be sucking the bubbles down as well. As soon as we did that, the shot had the feeling we wanted."

Two shots were farmed out to The Post Group, with whom Digital Domain had set up a farm-out deal from the beginning of the project. Rob Legato supervised the work there, which consisted of compositing miniature and greenscreen elements into live-action plates for a scene inside the first-class lounge in which the band plays on as passengers continue to enjoy the evening, blissfully unaware of the impending disaster. "The ceiling and background walls in that shot were all miniature," said Camille Cellucci, "built and photographed at Digital Domain. Those elements were then turned over to The Post Group." Likewise composited was a shot that starts at a chandelier in the tea room- also a miniature- then pans down to Rose's face as she watches a little girl being instructed on how to place a napkin in her lap.

Richard Malzahn and his team at Perpetual Motion Pictures were tagged to execute some fast cable and wire removals for the show and ended up doing ten or so shots. "In addition to the wire removal, they handled some post moves that we decided needed to be digital rather than

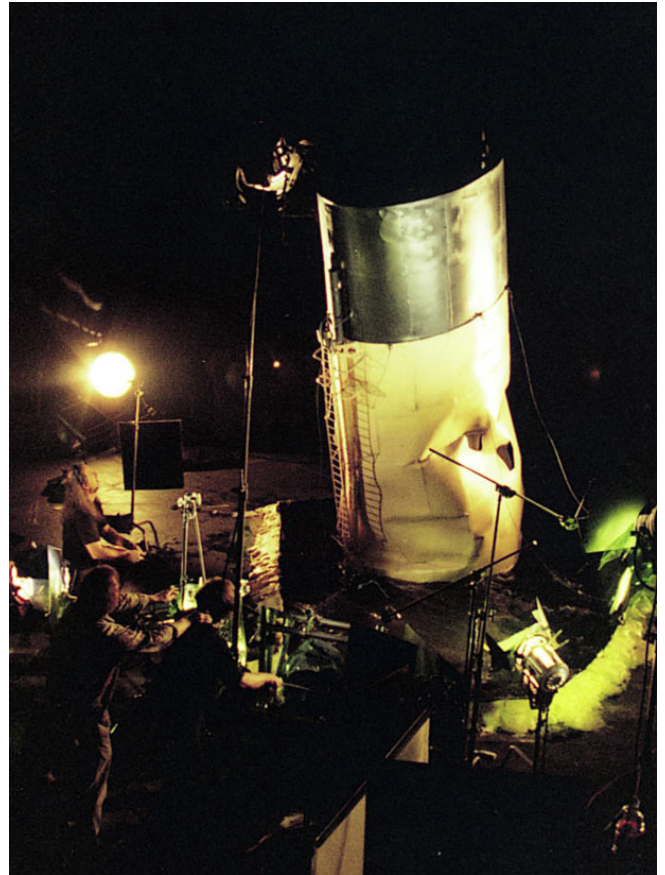
optical- repo moves, that type of thing,” noted Cellucci. “Plus, they did a few tricky things, like removing a camera shadow on a porthole shot of Jack as the camera pans along the ship. They also removed a ‘bathtub ring’ around the ship- formed from its sitting level in the tank for weeks- that became visible once the set was tilted.”

Pacific Title Digital did two shots for the film, one of which was so exacting, it was not finalized until very near the end of postproduction. “They handled a couple of the shots of the Titanic going out to sea,” said Cellucci, “using some of the Lane Victory elements shot by Digital Domain. One of them was a wide, high-angle day shot of the ship in a big ocean, with a trail of smoke streaming out and a big wake.” Digital Domain provided all of the elements to Pacific Title Digital for compositing, including a computer generated Titanic. “Pac Title covered the Lane Victory with the CG Titanic, retaining the wake and water from the original plate. The tricky part was getting the smoke to move correctly. They had to do quite a bit of blending and soft-edge splitting to get the color just right on the smoke, and a lot of compressing and expanding to get it to look right in combination with the ship and the wake.” The company’s other contribution was for a shot after the Titanic leaves port in Ireland, filmed from the Lane Victory off the coast of Catalina. “The island was in the background, so they changed the brown of Catalina to the green hills of Ireland.”

Pacific Title Optical- a sister company- did the optical work for the show, from commonplace dissolves and fades to flop shots and optical moves. “We ended up with somewhere between 350 and 400 opticals, some of which were very complex. The whole end sequence that begins with Rose getting on the lifeboat and ends with the appearance, the next morning, of the Carpathia is a long, tricky optical dissolve.”

The arrival of the Carpathia brings Old Rose’s story to an end. Inspired by a Ken Marschall painting, the rescue tableau was made up of several elements, including a digital matte painting provided by Matte World Digital that reveals survivors in lifeboats, icebergs and the Carpathia on the horizon. The company was assigned the shot in May and given only a couple of weeks in which to complete both the matte painting and the final composite. “When we first got the shot,” recalled Matte World Digital co-founder Craig Barron, “we considered building a CG Carpathia. But then Chris Evans suggested that he paint it, and I thought: ‘Of course. We do matte paintings here.’ Chris is so good at being able to render realistic imagery, we decided it would be the best and fastest way to go. If the Carpathia had been in several other shots, we would have approached it as a 3-D model; but considering the long-distance view of the ship, it didn’t need to change so much dimensionally as just drift slightly on the horizon. A matte painting was a perfectly good solution.”

Referencing both the Ken Marschall painting and some watercolor sketches by an artist who was on the Carpathia when the Titanic survivors were recovered, Evans created a traditional, two-by-four-foot, acrylic-on-masonite matte painting, which was photographed and scanned into the computer, then extracted for compositing into an ocean plate with lifeboats in the foreground. An additional lifeboat- photographed greenscreen at Digital Domain- was incorporated in the far distance. Iceberg elements were two-foot-tall models made out of foam, wax and plaster of Paris, filmed at dusk to simulate the lighting conditions in the dawn rescue scene. Digital painting touchups, rendered by Evans after the model photography was scanned into the computer, refined the colors and provided a subtle reflection on the icebergs.



Working with a model built by Don Pennington, 4-Ward Productions shot elements for a sequence in which the Titanic's forward funnel collapses.



Matte artist Chris Evans of Matte World Digital painted a view of the rescue ship Carpathia, which was digitally composited with model icebergs and a live plate of lifeboats shot in Mexico.

Beyond providing him with an increasingly rare opportunity to paint with brush and acrylics rather than a computer keyboard and mouse, Chris Evans had another reason for being particularly invested in his Titanic contribution. "My great-grandfather, John Bartholomew, worked for the White Star Line as chief victuals officer," explained Evans. "He was friends with Captain Smith for many years- in fact, I have a family photo of him standing with Captain Smith. He was supposed to have been on the Titanic on her maiden voyage- not as an officer, but as a company VIP. The night before she sailed, however, he got very sick and canceled. His trunks were on the ship- and some of the early reports listed him as a casualty. When he heard that the Titanic went down with so many of the friends he had worked with for thirty or forty years, he was heartbroken. It's a strange twist of fate- this particular matte artist would not have been here to do this shot if his great-grandfather hadn't missed the boat."



Matte artist Chris Evans of Matte World Digital painted a view of the rescue ship Carpathia, which was digitally composited with model icebergs and a live plate of lifeboats shot in Mexico.

A sequence depicting the Carpathia's arrival in New York harbor with the Titanic survivors on board featured two shots composited by Digiscope, where Inferno artist Grady Cofer tracked a model Statue of Liberty into the distance as the camera sweeps along the bow of the ship. "First unit gave Digiscope a plate of Rose on the deck of the Carpathia," said Cellucci, "and Digital Domain contributed a model element of the Statue of Liberty. In addition to compositing the two elements, Digiscope also did some match-move work to blend the camera moves on the ship and on the statue model, then some overriding moves to make it look as if the ship was actually passing by it." To authentically re-create the rainy weather conditions that were present when the Carpathia arrived, Digiscope layered motion control plates of rainfall- shot by Digital Domain - into the scene, with Cofer tracking CG particle rain into the foreground to tie all of the elements together. Glows were added to the statue's torch and crown to illuminate the rainfall.

Guided by the coordination efforts of Camille Cellucci and her team, and by Jim Cameron's very specific and always well-articulated vision, seventeen different companies- more than had ever been assembled for a Cameron film- came together on Titanic to create effects that were both uniform in style and of exceptionally high caliber. "It was such a wonderful surprise," reflected Cellucci. "Having never experienced the boutique world before, it was easy to underestimate what these smaller companies could do. So for me, it was a terrific experience learning what a huge reservoir of talent we have and how proficient so many of these boutique outfits are. I think we need both. We need the big, full-service companies to pull off the kinds of things that Digital Domain did on Titanic. But the smaller companies- coming together for their individual specialties- are equally invaluable. Having both provides multiple options for making movies."

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TITANIC

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Motion Control and
Miniature Photography
Green Screen & Compositing for
the "Engine Room" sequence.

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